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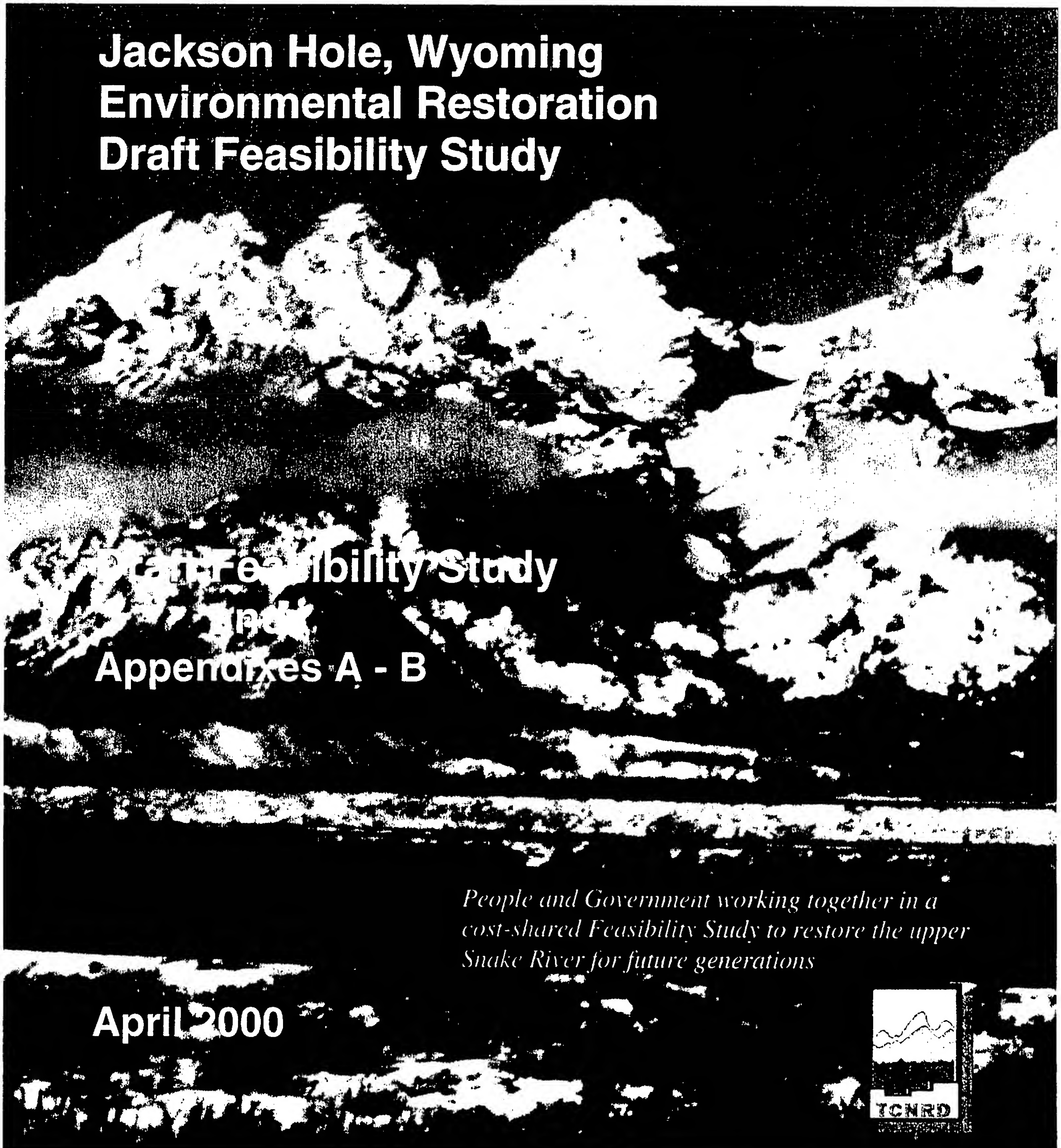

Jackson Hole, Wyoming
Environmental Restoration
Draft Feasibility Study

Draft Feasibility Study
and
Appendixes A - B

People and Government working together in a cost-shared Feasibility Study to restore the upper Snake River for future generations

April 2000

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The *Jackson Hole, Wyoming, Environmental Restoration Feasibility Report Draft April 2000* is the draft product of a 4-year, cost sharing feasibility study conducted by the U.S. Army Corps of Engineers, Walla Walla District, in partnership with Teton County, Wyoming, and Teton Conservation District, Wyoming. The report recommends an environmental restoration project on a 22-mile reach of the upper Snake River from Grand Teton National Park to South Park Elk Feedgrounds. The goal of the recommended project is to restore diverse and sustainable aquatic, wetland, riverside, and terrestrial habitats within the study area.

If you would like additional of the final version of the report copies (free of charge until no longer available), please contact, Mr. Stan Heller, Project Manager, U.S. Army Corps of Engineers, 201 North Third Avenue, Walla Walla, Washington 99362 (or send e-mail to: Stanley.G.Heller@nww01.usace.army.mil or telephone at 509-527-7258). The EA (Appendix H) of the report is also available at website: http://www.nwwusace.army.mil/reports/jackson.

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Environmental Restoration
Draft Feasibility Study

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Jackson Hole, Wyoming, Environmental Restoration Feasibility Study

EXECUTIVE SUMMARY

Background: In 1990, the U.S. Congress authorized the U.S. Army Corps of Engineers (Corps) to conduct the *Jackson Hole, Wyoming, Environmental Restoration Feasibility Study* (*Feasibility Study*) through the General Investigations Program. The purpose of the study was to investigate the feasibility of restoring fish and wildlife habitat that was lost as a result of construction, operation, and maintenance of the Jackson Hole Flood Control Project levees completed in 1964.

The study area is located in and along the Snake River near Jackson, Wyoming, in Teton County (see Plates 1 and 2 in the *Feasibility Study* for vicinity and project location maps). The primary local sponsor is Teton County, Wyoming. The study area borders the National Elk Refuge and is in close proximity to Grand Teton and Yellowstone National Parks.

Prior to construction of the levee system, the study area was characterized by a complex system of braided river channels and wooded islands that provided highly diverse and productive habitat for both aquatic and terrestrial species. The levees have contributed significantly to reducing flood damage within the river corridor, but they have also changed the physical character of the river system, resulting in river instability and severe habitat loss and degradation.

Existing and Historic Conditions: An assessment of existing and historic conditions was conducted for the study. Categories of conditions evaluated included hydrology and hydraulics, environmental resources, geology, geomorphology, and socioeconomics. Technical studies identified the major source of problems in the study area to be river channel instability. The main river channel has a tendency to fill and shift. This tendency has been intensified dramatically within the levee system. As the river changes its course, it can impinge on river island habitats, often resulting in complete destruction. With the loss of these island habitats, many species can no longer survive, especially during the area's harsh winters. Environmental studies confirmed that systematic channel instability has resulted in reduced diversity of species and diminished production of vegetation in area habitats. Without intervention, the remaining habitats in the study area will continue to become gravel bars with a drastic reduction in the diversity of animal and plant species.

Study Objectives: The overall goal of the recommended Jackson Hole Environmental Restoration Project supported by this study is to restore diverse and sustainable aquatic, wetland, riverside, and terrestrial habitats within the study area. Specific objectives are to investigate the feasibility of: (1) restoring river channel stability; (2) protecting remaining diverse habitats; (3) restoring diversity and sustainability to degraded habitats; and (4) restoring degraded habitats for threatened and endangered species.

Study Methods: The study area encompassed 25,000 acres of the floodplain of the Snake River near Jackson, Wyoming. The area was reduced to 12 potential restoration areas, with selection based upon the extent of habitat degradation and the highest probability of successful restoration. These 12 areas were then screened to identify the top 4 priority sites for detailed study; identified as Areas 1, 4, 9, and 10 (see Plates 3 and 4 in the *Feasibility Study* for maps of these locations). Innovative management measures were developed to protect and restore riverside and aquatic habitats at these sites. Based on the information developed through evaluation of a habitat restoration demonstration project, engineering studies, experience from the operation and maintenance of the flood control project, and other studies, management measures were identified for each of the sites to formulate the restoration plan for the entire river corridor.

Evaluation Criteria: Sixteen alternative restoration plans were evaluated based upon the criteria of environmental effectiveness and economic efficiency. Environmental habitat impacts were evaluated using three habitat models; one developed as part of this *Feasibility Study* for aquatic habitat and two developed by the U.S. Fish and Wildlife Service for riparian habitat. Cost effectiveness and incremental cost analysis identified the plans that were the best investments for producing varying levels of aquatic and riverside habitats.

Restoration Plans: Two restoration plans were determined to be feasible: the *Initially Proposed Plan* (developed within this study) and a second, more extensive, *Progressive Plan,* that is the result of subsequent management and sponsor review of this study as well as coordinated partnering among regional agencies, interest groups, and the study team.

a. Initially Proposed National Ecosystem Restoration Plan: The initially proposed National Ecosystem Restoration Plan (NER Plan) involves implementation at study Areas 1, 4, 9, and 10.

The initially proposed NER Plan is estimated to create a total of 104,277 aquatic habitat units (an increase of 20 percent) over the future without-project condition and a total of 11,464

riparian habitat units (an increase of 108 percent) over the future without-project condition. The proposed restoration will also improve habitat for multiple threatened and endangered species that depend on healthy and diverse river-related ecosystems. Threatened and endangered species that have been witnessed in the project area include the bald eagle, peregrine falcon, whooping crane, grizzly bear, and gray wolf.

The initially proposed NER Plan is estimated to have a total cost of $26.3 million.

b. ***Progressive Plan:*** The Progressive Plan involves restoration of the entire 22-mile reach of the Snake River starting approximately 2 miles downstream of Moose, Wyoming, to Flat Creek at South Park National Elk Feedgrounds. The Progressive Plan provides the greatest opportunity for environmental restoration of all impacted areas of the Snake River below Grand Teton National Park and above the canyon section of the river managed by the U.S. National Forest Service.

The Progressive Plan is estimated to create a total of 398,970 aquatic habitat units (an increase of 20 percent) over the future without-project condition. The Progressive Plan will also create an estimated total of 43,862 riparian habitat units (an increase of 108 percent) over the future without-project condition. The proposed Progressive Plan will improve habitat for the threatened and endangered species (*i.e.*, the bald eagle, peregrine falcon, whooping crane, grizzly bear, and gray wolf) mentioned in the initially proposed NER Plan, but with habitats restored over the entire 22-mile reach of the Snake River. The Progressive Plan provides the opportunity for greater ecosystem influence due to the restoration of highly degraded habitat over a larger geographic area. The expanded restoration effort will provide greater synergistic effect on adjacent habitats landward of the levees. The area to be restored under the Progressive Plan includes all areas where levees were constructed to provide flood protection without compromising flood protection.

Prior to restoration, all project areas added under the Progressive Plan will require the same degree of analysis as was performed in the *Feasibility Study*. Efficiencies will be realized since additional analysis will occur only in the Planning, Engineering, and Design Phase and not be repeated in another feasibility study. The following will be needed: hydraulic studies; fish and wildlife analyses to determine the most appropriate areas to provide restoration features; and a National Environmental Policy Act (NEPA) review.

The Progressive Plan will use a phased construction approach, implementing restoration in Areas 1, 4, 9, and 10 before other areas. The Progressive Plan will enable potential local sponsors to restore sections of the river more quickly and efficiently without the cost and time required for additional feasibility studies. Advancements in ecosystem restoration will occur as a result of the Planning, Engineering, and Design Phase applied to the first four sites and lessons learned from adaptive management of those sites through monitoring.

The cost per mile of restoration under the Progressive Plan varies along different parts of the river. The total cost of the Progressive Plan is estimated at $52.3 million.

Cost Sharing: The local sponsor, Teton County, has indicated a willingness to pay a percentage (35 percent) of construction costs consistent with current Federal cost-sharing guidelines. A long-term monitoring and maintenance plan has been developed to ensure that the project performs as designed. The first 5 years of this plan have been included in the construction cost of the project. After this 5-year period, Teton County has indicated a willingness to assume all responsibilities for monitoring, operating, and maintaining the project consistent with current operation and maintenance regulations. Teton County accepts responsibility for obtaining all lands, easements, rights-of-way, relocations, and disposals as required for project construction, operation, and maintenance of all areas proposed for construction.

Environmental Compliance: An Environmental Assessment (EA), Section 404(b)(1) Evaluation, and a draft Finding of No Significant Impact (FONSI) have been prepared and approved for the Jackson Hole Environmental Restoration Project for Areas 1, 4, 9, and 10. These documents describe the effects of restoring habitats in the four areas proposed for project implementation under the initially proposed NER Plan. Public forums and meetings were held to allow interested parties to ask questions and provide comments on the proposed project. Supplemental EA's or appropriate NEPA documents will be prepared for any additional implementation areas identified in the Progressive Plan during the Planning, Engineering, and Design Phase.

Recommendation: Both the initially proposed NER Plan and the Progressive Plan will restore and protect important fish and wildlife habitats impacted by the Snake River Federal Flood Control Project. Both plans will provide restored habitats for multiple threatened and endangered species. Both plans will enhance diversity of animal and plant species in a geographical area in which fish and wildlife play a large part in regional and national economies. The Progressive Plan would result in optimal restoration over a more extensive portion of this

outstanding natural environment. Based upon this *Jackson Hole, Wyoming, Environmental Restoration Feasibility Study,* implementation of the Progressive Plan is recommended as a first choice with the Initially Proposed Plan providing a second viable alternative.

Feasibility Study: The following *Feasibility Study* summarizes the planning process, results, and recommendations for environmental restoration of the Jackson Hole study area. The study examines: existing conditions; prior studies and reports; projected conditions without restoration; plan formulation; the initially proposed NER Plan; plan implementation and coordination; and public views and comments. Details of technical studies are provided in the following Appendixes: Hydrology, Ground Water, Engineering, Economic, Real Estate, Environmental Assessment, and Fish and Wildlife.

1. INTRODUCTION

1.1 Study Authority

The Jackson Hole Flood Control Project was authorized in the Flood Control Act of 1950, and provided flood protection by levees and revetment along the Snake River in Jackson Hole, Wyoming. The Jackson Hole Flood Control Project was completed in the fall of 1964, and the sponsor was Teton County. Additional levees were added to the system by other agencies and by emergency flood fight operations of the U.S. Army Corps of Engineers (Corps) and Teton County through 1997.

Authority to operate and maintain the Jackson Hole Flood Control Project was granted by Section 840 of the Water Resources Development Act of 1986, Public Law (PL) 99-662 (WRDA 86), to the Secretary of the Army, including additions and modifications constructed by non-Federal sponsors, provided that the local sponsor provides the first $35,000 in any one year (adjusted for inflation). The Corps signed a Local Cooperative Agreement with Teton County in September 1990, after completion of a Decision Document and Environmental Impact Statement (EIS). The Corps assumed operation and maintenance (O&M) responsibility for the levee system on the Snake and Gros Ventre Rivers in Jackson Hole, Wyoming.

The Jackson Hole, Wyoming, River and Wetland Restoration Study was authorized by the U.S. Senate Committee on Environment and Public Works in a Study Resolution of June 12, 1990. The scope of the study was to determine the feasibility of providing environmental restoration to wetland and riparian habitats located between the flood control levees. Teton County, the local sponsor for the proposed environmental restoration project by the Corps, would provide funds in accordance with cost sharing requirements specified in WRDA 86, as amended.

As required by the National Environmental Policy Act of 1969 (NEPA) and subsequent implementing regulations promulgated by the Council on Environmental Quality (CEQ), an Environmental Assessment (EA) was prepared to determine whether the proposed environmental restoration project constitutes a "major Federal action significantly affecting the quality of the human environment" and whether an EIS is required.

1.2 Study Purpose and Scope

The purpose of this *Jackson Hole, Wyoming, Environmental Restoration Feasibility Study (Feasibility Study)* is to investigate the feasibility of restoring fish and wildlife habitat that was lost as a result of construction, operation, and maintenance of levees of the Jackson Hole Flood Control Project, including levees constructed by non-Federal interests. The study area is located along the Snake River, near Jackson, Wyoming, in Teton County.

While the levees have contributed significantly toward reducing flood damage potential along the river corridor, over time the levees have significantly changed the physical character of the river system and contributed to the loss of environmental resources. The environmental restoration project supported by this *Feasibility Study* is needed to prevent further degradation and destruction of environmental resources within the study area and to facilitate recovery of lost aquatic and terrestrial habitat. A restoration project has high potential for restoring fish and wildlife habitat through enhancement and restoration of the aquatic and riparian environment, including wetland and riparian vegetation and in-stream fisheries habitat.

1.2.1 Study Goal

The overall goal of the *Feasibility Study* is to investigate the feasibility of restoring diverse and sustainable riverine (aquatic, wetland, riparian, and terrestrial) habitats within the study area.

1.2.2 Specific Objectives

Specific study objectives include investigating the feasibility of:

- Restoring channel stability and in-stream habitat values.
- Protecting remaining diverse (wetland/riparian/terrestrial) island habitats.
- Restoring diversity and sustainability to degraded island habitats.
- Restoring degraded habitats for threatened and endangered species.

1.3 Study Area

The original study area defined in the reconnaissance report encompassed 25,000 acres of the 500-year floodplain of the Snake River and its tributaries in the vicinity of Jackson Hole, Wyoming. The study area was limited to the reach between the town of Moose (near the southern boundary of Grand Teton National Park), and the U.S. Highway 26 Bridge over the Snake River about 7 miles south of Jackson. Twelve potential restoration sites (Plates 1, 2, and 3) were included in the study area. The current *Feasibility Study* area examines only four potential restoration sites: Areas 1, 4, 9, and 10, and is limited to the Snake River between the Gros Ventre River confluence and the aforementioned Highway 26 Bridge (Plate 4).

1.4 Study Area Physical Characteristics

Jackson Hole is a valley about 10 miles wide and 35 miles long situated along the Snake River in northeastern Wyoming (see Plate 2). It is bounded by the Teton Range on the west, the high plateaus of Yellowstone National Park to the north, and the Gros Ventre Range to the east. Valley elevations range from about 5,900 feet at the Highway 26 bridge over the Snake River to 6,800 feet in the vicinity of Jackson Lake, with an average elevation of about 6,200 feet in the Federal levee project area. Peak elevations rise to over 13,000 feet.

1.4.1 Climate

The climate of the area from Jackson to Moran, Wyoming is typical of high-elevation, Rocky Mountain valleys. During summer months the area has an abundance of sunshine with low humidity and high evaporation during the daytime. The growing season between killing frosts is limited by extreme diurnal fluctuations in temperature and resulting cold nights. Surrounding mountain areas seldom experience a month without freezing temperatures. Thunderstorms are frequent during the summer months, but individual occurrences affect only limited areas. Resultant storm runoff in the Snake River and major tributaries is small in comparison to stream flows resulting from snowmelt.

Climatological records at Jackson show an average annual temperature of 38 degrees Fahrenheit (°F) with period-of-record extremes of minus 52 °F and 101 °F. Temperatures as low as minus

63 °F have been recorded at Moran. Daily minimum temperatures below freezing usually occur at Jackson from early September to mid-June and freezing temperatures have been known to occur in any month of the year. The average frost-free period (growing season) is about 50 days at Jackson.

The Jackson Hole area is affected principally by moist Pacific maritime air masses brought into the region by prevailing westerly winds, and the valley is somewhat within the rain shadow of the Teton Range. Frequently, cool polar or warm continental air masses invade the region, displacing or modifying the effects of the maritime air masses. These latter types are mainly responsible for the valley's clear weather and low humidity, as well as its diurnal and seasonal temperature extremes. Jackson Hole is located just west of the Continental Divide, and, in addition to storms from the west, the basin can be affected by orographic lifting of air masses from the north and east. During the summer, subtropical air from the southern Rockies can also be a source of moisture for thunderstorms. However, runoff from these storms tends to be highly localized, and Teton County authorities report that storm runoffs do not reach approach damaging levels.

1.4.2 Topography

The topography of the Jackson Hole valley is dominated by depositions of fluvial material by the upper Snake River, by historical and present tectonic uplifting, and by glaciation. The valley floor is presently underlain by deep deposits of alluvial and glacial Quaternary gravels, sands, and debris. Jackson Hole was formed by differential tectonic uplifting of the Teton Range, which has influenced the present position and channel form of the Snake and tributary rivers. Prior to levee construction, the major rivers and tributaries of the Jackson Hole floodplain had cut braided channels through glacial outwash plains. Braided channels result from a combination of high sediment loads, relatively steep channel gradients, and noncohesive banks. Braided channels are subject to frequent avulsion (channel switching) and lateral channel migration. They are very prone to flooding because of their relatively shallow depth when compared to width, and because of their characteristically unstable or noncohesive banks.

1.4.3 Drainage

The headwaters of the Snake River originate in Yellowstone National Park to the north of Jackson Hole. After passing through Jackson Lake, the river enters the Jackson Hole floodplain. Principal upstream tributaries are the Lewis River, Pacific Creek, and Buffalo Fork. The Gros Ventre River is a relatively large tributary, collecting runoff from a little over 25 percent of the total drainage area above the U.S. Geological Survey (USGS) gage site, Snake River below Flat Creek. It enters the Snake River from the east within Federal levee project limits several miles upstream from the Jackson-Wilson Bridge. Fish, Flat, Mosquito, Cottonwood, Taylor, Squaw, and Spring Creeks are among the smaller tributaries that enter the Snake River in the vicinity of the four study areas. Flat Creek enters the Snake River at the downstream end of the valley just below the Highway 26 Bridge.

The Snake River and its tributaries in the upper Snake River Basin have regular patterns of natural seasonal flow with high flows during the months of May through July, receding flows in August and September, and low flows in the months of October through April. High flows in the late spring and early summer result from melting of the winter-accumulated snowpack, sometimes augmented by rainstorms. Winter flooding due to thawing conditions and rain-on-snow conditions can occur, but rarely result in damaging flows. For the period of record, maximum annual peak discharges have always coincided with the spring snowmelt season. Total annual runoffs for a given area vary with the amounts of precipitation received during the snowpack accumulation and the snowmelt season

Regulation of water levels by the use of storage space in Jackson Lake reduces the Snake River flow during October through May and early June and augments Snake River natural flows during July, August, and September in order to satisfy downstream irrigation requirements. Further coordination with the U.S. Bureau of Reclamation (USBR) regarding the regulation of Jackson Lake could result in enhancement of environmental benefits presented in this *Feasibility Study*.

2. EXISTING PROJECTS, PRIOR STUDIES, AND REPORTS

2.1 Existing Flood Control Levees

The original design of the Jackson Hole Federal Levee System provided for approximately 23 miles of continuous, revetted levee along the Snake River. The Federal levee project begins 4 miles below the Snake River Bridge near Moose, Wyoming, and ends about 4 miles below the Jackson-Wilson Bridge (Plate 5). The Federal levees were completed in 1964. Over the years, many post-project levees, commonly referred to as the "non-Federal levees," were constructed outside the limits of the Federal levee project. Each non-Federal levee was intended to solve problems for localized areas. Various Federal, State, and local agencies, sometimes with private assistance, constructed these levees. The non-Federal levees include a continuous set of levees on the Gros Ventre River downstream of the Grand Teton National Park boundary and a number of discontinuous levees on the Snake River downstream of the Federal project levees. Most of the Snake River non-Federal levees are along a reach that extends 9 miles from the end of the Federal project downstream to the U.S. Highway 26 Bridge. One non-Federal levee (95 Ranch) is located on the left bank just upstream of the Federal levees.

2.1.1 Federal Levees

With the enactment of the WRDA 86, these levees are now part of the Federal levee project, and the U.S. Army Corps of Engineers, Walla Walla District (Walla Walla District) has O&M responsibility for all of the Jackson Hole levees. The Federal/non-Federal terminology is retained in this report because it has been used in the numerous prior Jackson Hole studies and is familiar to local interests. The original Federal levee system extends from river mile (RM) 961.0 to RM 947.6 on the right bank of the Snake River. On the left bank, the levees begin at RM 961.8 and end at RM 947.6, with a break between RM 957.2 and RM 952.8. The break is in the vicinity of the Gros Ventre confluence in a reach with narrow floodplains left of the main channel. Levees were aligned to follow the edge of the main channel with slight setbacks to avoid underwater excavation of the riprap toe trench. The alignments were then smoothed to reduce direct impingement of the river as the main channel meanders between the levees. The gap between the levees is about 1,000 to 1,600 feet, compared to the natural active meander belt

width of 1,000 to 4,000 feet. The separation was designed to restrict the river enough during flood flows to reduce debris accumulation and log jams.

The cross-sectional profile of the levee consists of a lower, toed-in, riprapped portion with a 1 vertical on 2 horizontal slope and an upper cobbled portion with a 1 vertical on 4 horizontal slope (see Plate 6). The levee was designed to contain floods of 45,000 cubic feet per second (cfs) below the mouth of the Gros Ventre River and 37,000 cfs above the confluence. Three feet of freeboard was added to the computed water-surface profile to arrive at a top-of-levee design height. Above the confluence, the design elevations for the revetments were set at an equivalent flow height, about 4 feet below the computed profile for the standard project design flood. Recent hydraulic analysis has cast doubt on the ability of the present levee to pass the original design flow.

2.1.2 Non-Federal Levees

The Corps constructed many of the non-Federal levees along the Snake and Gros Ventre rivers in Teton County during emergency flood fight operations (see Plate 5). These levees supplemented the flood control efforts of Teton County agencies. The U.S. Soil Conservation Service, the Wyoming Department of Transportation, the Wyoming Game and Fish Department (WGFD), and Teton County constructed other levees. Projects constructed under Federal emergency disaster assistance authorities, such as PL 84-99 or PL 93-228, are categorized as non-Federal unless they were constructed as a replacement for a damaged Federal project. Such emergency projects were not necessarily constructed to the design standards imposed on Federal project levees.

Large sections of the non-Federal levees were intended primarily to protect the river bank, while other segments tend to limit the channel's natural migration. Portions of the levees also act as channel plugs to prevent floodwater from flowing into certain side channels. Riprap protection was included in construction of segments that needed to resist direct impingement and erosion. Subsequently, additional segments were revetted when the main channel shifted closer to the offset levee portions.

2.2 Prior Studies and Reports

The Snake River and tributaries in the vicinity of Jackson, Wyoming, has been the subject of numerous water resource and environmental resources studies. Past efforts of interest to this *Feasibility Study* have been conducted by the Corps and other Federal, State, and local agencies. These studies have focused on issues ranging from flood protection, geological quarry investigations, environmental assessments, O&M of existing projects, project modifications for improvement of the environment, and fish and wildlife habitat restoration. A description of pertinent prior studies and reports follows.

2.2.1 Jackson Hole, Wyoming, Flood Damage Reduction and Fish and Wildlife Restoration Reconnaissance Study, June 1993

The *Jackson Hole, Wyoming, Flood Damage Reduction and Fish and Wildlife Restoration Reconnaissance Study* responded to two authorities: (1) The *Jackson Hole River and Wetland Restoration Study,* authorized by the U.S. Senate Committee on the Environment and Public Works to "mitigate for fish and wildlife impacts;" and (2) the *Snake River in Wyoming, Interim Upper Snake River and Tributaries Study,* authorized by the U.S. Senate Committee on Public Works to determine whether modification of the upper Snake River would be advisable.

This *Feasibility Study* also addresses both authorities in a combined study effort which allows a coherent and consistent formulation of the without-project scenario for the study area. This consistent picture of without-project conditions provides a common base to formulate alternatives addressing both authorized study purposes (*i.e.*, flood damage control, and fish and wildlife restoration). The comprehensive approach better serves the public while increasing overall management efficiency. The combined approach is also consistent with the *Position Paper*, issued August 14, 1992 by the Walla Walla District, developed with the Corps, North Pacific Division, and approved on October 21,1992 by Corps Headquarters (HQUSACE).

2.2.2 Snake River in Wyoming Interim, Upper Snake River and Tributaries Study (General Investigations)

The *Snake River in Wyoming Interim Study* was first initiated in 1961 in the *Joint Report Upper Snake River Basin*, 1961 by the Corps and the USBR. The *Interim Report No. 6, Lower Jackson*

Hole Channel Project was published in April 1965. In this report, the Corps identified improvements to be done in the 8 miles of the Snake River below the Federal levee project and recommended that the levee system be completed to the U.S. Highway 26 Bridge. In August 1986, Teton County requested that the interim study be resumed to evaluate opportunities for reducing flood damage for the whole levee system. A draft *Preliminary Report,* completed by the Corps in December 1988, recommended that detailed levee modification studies be undertaken. Congressional commitments originally called for submittal of an interim report by November 1988, but this report was delayed while the Corps evaluated the economic feasibility of O&M as mandated by WRDA 86.

The Corps elected to prepare a decision document because insufficient resources were available to complete a feasibility study document. The preliminary study resulted in a draft *General Investigations (GI) Decision Document* dated June 1990. This document recommended detailed studies for extending the left bank Federal levee above the mouth of the Gros Ventre River and raising the Gros Ventre River levees to the 100-year protection level. The draft GI Decision Document was never finalized because of anticipation of resuming the Snake River in Wyoming Interim Study. The Snake River in Wyoming Interim Study resumed in March 1992 with a scheduled completion date for the feasibility report and EIS in 1993. Under this study, improvements to the levee system were evaluated.

A NEPA scoping meeting was held in Jackson, Wyoming, on March 4, 1992 to elicit comments about the proposed levee improvements from the public. Many local groups urged the Corps to implement a comprehensive planning approach to the entire levee system and to consider the effects that individual projects may have on the rest of the system. The Corps received several letters from individual property owners, local officials, and various organizations. These people stated their concern with a piecemeal evaluation and requested that the EIS for the possible extension of the left bank Federal levee and raising of the Gros Ventre levees consider the whole levee system. This reconnaissance report, which combines all area studies into one comprehensive study, is in response to those requests.

2.2.3 Jackson Hole Restoration Study (General Investigations)

The EIS process for the May 1990 O&M EIS resulted in numerous requests for the Corps to mitigate for environmental effects of levee construction. Public input on this subject generally

stressed the national significance of the affected resources. As a result, the Jackson Hole Restoration Study was authorized in the Water Resources Development Act of 1990 (WRDA 90) and funded for fiscal year (FY) 91 to determine how levees affected fish and wildlife and to recommend short-term and long-term restoration. The reconnaissance phase study was initiated in March 1991.

The O&M EIS process resulted in a Section 7 consultation with the U.S. Fish and Wildlife Service or Fish and Wildlife Service (USFWS) on endangered species (bald eagles). The Corps agreed to use the Restoration Study to evaluate short-term measures for spring creeks improvements that might be implemented under O&M funding. Therefore, this reconnaissance study identified specific short-term recommendations for solutions to implement the Section 7 agreement with the USFWS. The Record of Decision, signed September 1990, requires the Corps to improve the spring creeks to benefit bald eagles. Also, as part of these short-term measures, culverts for fish passage were to be modified in FY 92 as agreed to under Section 7.

2.2.4 Jackson Hole Section 1135 Study (Continuing Authority Program)

Under Section 1135(b) of WRDA 86, a fish and wildlife restoration demonstration project was approved for implementation in the Jackson Hole area. The original legislation provided for implementation of demonstration projects during a 2-year period, beginning November 17, 1986. However, Section 307(d) WRDA 90 added the demonstration program to the Corps Continuing Authority Program, resulting in the removal of funding limitations of the original demonstration project allocation. The initial estimate was for a $480,000 island protection and spring creeks restoration project.

The project proposed for implementation under Section 1135 will provide information on spring creeks restoration design and costs. The Section 1135 is intended to serve as a prototype for identifying water relationships in the riparian zone between the river, groundwater, and surface waters behind the levee; and how these relationships directly relate to the larger feasibility study effort and the potential recommendations. This information is also needed to implement some of the objectives of the Section 7 agreement.

The draft *Detailed Project Report and Environmental Assessment (DPR/EA)* was completed in January 1992. The draft *DPR/EA* proposed protecting a wooded island and restoring flows to

some of the alluvial channels cut off by one segment of the levee system in the Jackson Hole area. On April 21, 1992, the island protection was deferred because of concern about downstream impacts that had not yet been evaluated. It was recommended that the island protection proposal be evaluated in a feasibility study that considers system-wide impacts and interrelationships.

2.2.5 Snake River at Spring Creek Section 205 Study (Continuing Authority Program)

Because of local problems of avulsion in the Spring Creek confluence area, Teton County requested a Section 205, small flood control project, study, which was initially approved by the Corps. This study was later deferred until comprehensive solutions (*i.e.*, this *Feasibility Study* along with the other flood damage reduction solutions at other sites in the area) could be evaluated.

2.2.6 Other Prior Studies and Reports

2.2.6.1 South Park National Elk Feedgrounds Section 205 Study (USACE, 1951)

A Section 205 *Detailed Project Report: South Park (Elk) Feedgrounds Location, Snake River, Wyoming,* dated September 5, 1951, recommended levee improvements to protect the Elk Feedgrounds. The Corps did not construct a project, but later the WGFD constructed a levee.

2.2.6.2 Upper Snake River Basin Study (USACE, BUREC, 1961)

A joint study of the upper Snake River Basin by the Corps and the USBR was completed in 1961. Corps participation was authorized under the Upper Snake River and Tributaries study authority. This study recommended extending the left bank Federal levee downstream to the U.S. Highway 26 Bridge, and a 0.6-mile section at the lower end of the right bank of the project where the current Evans Levee is located. Parts of the left bank levee were constructed over the years as the Federal Extension, Imenson, Spring Creek, Game and Fish, and South Park Levees. These were non-Federal intermittent levees.

2.2.6.3 Upper Snake River and Tributaries Study Interim Report No. 6 (USACE, 1965)

The *Upper Snake River and Tributaries Study, Interim Report No. 6, Lower Jackson Hole Channel Project, Snake River, Wyoming,* dated April 1965 recommended construction of levees on the sites of the current Sewell/Taylor Creek Levees and the Imenson Levees. The Sewell Levee was constructed by the Corps for the Soil Conservation Service in 1977, the Lower Taylor Creek Levee was constructed by the Corps in 1969 under Operation Foresight (PL 84-99), and the Imenson Levees were constructed from 1967 to 1971 under flood fight operations.

2.2.6.4 Sec. 208 Emergency Clearing and Snagging Study (USACE, 1968)

A Section 208 *Emergency Clearing and Snagging Project Report, Snake River, Wyoming, RM 955 to RM 965.5, Imenson Location,* dated October 4, 1968, recommended clearing and snagging this channel section under the Continuing Authority Program. This work resulted in an unrevetted setback levee referred to as the Upper Imenson.

2.2.6.5 Jackson Hole, Wyoming, Flood Protection Project Letter Report (USACE, 1988)

An unpublished draft Letter Report, completed in January 1988, looked at various alternatives for improving the levee system and the studies required evaluating these alternatives. This study was followed up by the O&M EIS. Limited clearing and snagging was completed in 1989 to remove snags from the river because the snags were affecting the levees.

2.2.6.6 Geological Reconnaissance and Quarry Investigation Reports (USACE, 1989, 1992)

A Geological Reconnaissance and Quarry Investigation Report was completed in April 1989 that located a number of potential quarry sites for riprap to maintain the levees under O&M authority. A second report prepared in December 1992, entitled *Jackson Hole, Wyoming, Geologic Investigations of Potential Quarry Sites* investigated in greater depth several of the potential quarry sites.

2.2.6.7 Hydrologic and Hydraulic Investigations Report (USACE, 1990)

A Hydrologic and Hydraulics Investigations Report was published in December 1990; it summarized the hydrological work completed to date on various studies in Jackson Hole. Additional sedimentation analysis information is included in this report as Appendix B, Hydrology.

3. WITHOUT-PROJECT CONDITIONS

3.1 Existing Conditions

An assessment of existing baseline conditions was conducted as part of the *Feasibility Study*. Categories of conditions evaluated include: Geology and Geomorphology, Hydrology and Hydraulics, Environmental Resources, and the Human Environment. The following pages provide summaries of the existing conditions assessment for each of these categories.

3.1.1 Geology and Geomorphology

Jackson Hole is an intermontane basin bounded on the west by the steeply sloping face of the Teton Mountain Range and on the east by the Gros Ventre Range. This basin was formed when a large block of the Earth's crust raised up along faults to form the Teton Range at the same time that the valley subsided (see Plate 7). Movement along the faults began during the formation of the Rocky Mountains approximately 9 million years ago and has continued to the present time. Pleistocene Epoch (approximately 3 million years ago) and recent movement along the Teton Fault, have been the dominant factors determining the positions of the streams on the floor of Jackson Hole, south of Jackson Lake. Large vertical displacements along the Teton and adjacent faults have exposed bedrock, primarily along the valley walls. As a result of Pleistocene glaciation, the valley floor is composed of a thick sequence of glacial sediments.

Large glaciers that advanced and retreated in the vicinity of Jackson Hole during the Pleistocene left behind a landscape abundant in glacial features. The Teton Range was carved by glacial ice, leaving behind high peaks, deep cirques, v-shaped canyons between the peaks, and moraine impounded lakes. The valley was the dumping ground for glacial debris as evidenced by numerous terminal and lateral moraines, not to mention the large blanket of material deposited on the valley floor. The present day stream morphology in the valley is generally referred to as a high energy braided system and is greatly influenced by the large amounts of glacially derived sediment that the streams must transport. The paths that the streams follow in the valley are, however, controlled by tectonic tilting of the bedrock beneath its thick sediment cover.

Downstream from the Gros Ventre confluence, several features suggest that the Snake River channel has been aggrading. These features include flat or convex valley cross sections, low or poorly defined channel banks, a wide meander belt, old channel scars indicating widespread shifting of the channel in the past, and tributary streams which turn abruptly on entering the valley and then flow parallel to the Snake River. Another contributing factor, that may possibly be influencing the parallel flow of tributary streams on the west side of the valley, is tectonic tilting of the Teton fault block. The gentle, but measurable, westward slope of the terrace surfaces, and the absence of alluvial fans along the western edge of the valley, suggest that tilting of the valley floor may still be in progress.

Some concern has been expressed that the river, if unrestrained, might suddenly shift westward into the lower Fish Creek Channel, permanently flooding the town of Wilson and surrounding developments. However, it could be argued that the river would have escaped its present channel and become permanently trapped against the eastern toe of the Tetons long ago if tilting were the predominant influence. The river has, in fact, overflowed into these areas during past floods. However, any sudden changes in the slope of the valley floor, resulting from earthquake activity, could result in major changes in the path of the Snake River. The Jackson Hole area is considered to be a highly active region.

3.1.2 Hydrology/Hydraulics

The existing condition assessment for hydrology and hydraulics is summarized below in the following sections: Precipitation, Runoff and Peak Discharges, Water-Surface Profiles, Erosion and Sedimentation, Flooding, Existing Levee System, Jackson Dam Operations, and Groundwater.

3.1.2.1 Precipitation

The average annual precipitation varies from about 16 inches at Jackson to about 60 inches near the summit of the Teton Mountain Range. Minimum and maximum annual precipitation totals vary from about 60 percent to 150 percent of the mean annual precipitation, respectively. The 6-hour maximum rainfall for the 100-year storm is in the range of 2 inches ± 0.5 inch, and the 24-hour maximum rainfall is in the range of 3 inches ± 1 inch.

Precipitation is rather evenly distributed throughout the year in the valley, but more concentrated at higher elevations in the winter. Due to the cool temperatures of this high-elevation area, the precipitation accumulates mainly as snow from October through May. Average annual snowfall varies from about 80 inches at Jackson to over 300 inches at high mountain snow courses. Maximum annual snow depths vary from about 2 feet to over 10 feet, depending on the location. Maximum depletion rates of snow normally occur during May and June, often resulting in flood conditions on the Snake River.

There are approximately six climatological stations in the Basin with long-term records. Currently, the National Weather Service (NWS) maintains 10 climate stations providing daily readings in the Snake River drainage above Alpine and perhaps a dozen stations providing similar climatic measurements in nearby basins. The Natural Resource Conservation Service maintains seven Sno-Tel stations in the upper Snake River Basin above Palisades Reservoir providing real-time snow water equivalent readings and limited temperature and precipitation information. As with the climatological stations there are numerous additional stations in nearby basins that have good correlation with the Snake River sites. The Natural Resource Conservation Service also coordinates and publishes semimonthly snow course measurements for 17 stations in the Snake River Basin above Palisades. About nine snow courses have long-term records, some of which are used by various agencies in conjunction with precipitation measurements in computing spring runoff forecasts. Representative climatological and snow course information is given in Appendix B, Hydrology.

3.1.2.2 Runoff and Peak Discharges

The Snake River and its tributaries in the upper Snake River Basin have regular patterns of natural seasonal flow with high flows during the months of May through July, receding flows in August and September, and low flows in the months of October through April. A summary hydrograph for the USGS gage, Snake River Below Flat Creek, is shown on Plate 8. High flows in the late spring and early summer result from melting of the winter-accumulated snowpack, sometimes augmented by rain storms. Winter flooding due to thawing conditions and rain-on-snow conditions can occur, but rarely results in damaging flows. For the period of record, maximum annual peak discharges have always coincided with the spring snowmelt season and sometimes persist for days or weeks. Total annual runoffs for a given area vary with the amounts of precipitation received during the snowpack accumulation and the snowmelt seasons.

Summer thunderstorms are common in the mountains. However, runoff from these storms tends to be highly localized, and Teton County authorities report that storm runoffs do not approach damaging levels.

The annual pattern of discharge in the Snake River (and the study reach) is substantially modified by the storage and release of water for irrigation from Jackson Dam, which forms Jackson Lake. Regulation by the use of storage space in the lake reduces the Snake River flow from October through early June. Corresponding to the peak irrigation season, high flows are released into the river from July to September. Sustained flows during the summer sometimes exceed 11,000 cfs, which approximates natural (pre-levee) bankfull discharge conditions. Regulation by Jackson Lake Dam is discussed in greater detail in Section 3.1.2.7 of this report.

The primary source for stream flow records is the USGS. Plate 9 depicts the current USGS hydrological reporting network in the upper Snake River Basin, with the study reach called out just downstream of the Gros Ventre River confluence. In addition to the USGS published discharge data at various gage stations, inflow and release data is available from the USBR for the Jackson Dam and Palisades Dam projects. The stations within the vicinity of the project reach are listed in Table 3.1.

Table 3.1 - USGS Stream Gaging Records

Station Name	Description	River Mile	Station #	Drainage Area	Period of Record	Extremes (Daily Flow)
Snake River Near Moran, WY [1]	1,000 feet downstream from Jackson Lake Dam 4.1 miles west of Moran	988.7	13,011,000	807 sm	1903-present	Max 15,100 cfs June 12, 1918 [2] Min 0.30 cfs Oct. 28, 1969
Snake River Near Wilson, WY [1]		951		2,500 sm [3]	1972-1975	
Snake River Below Flat Creek, Near Jackson, WY [1]	1 mile downstream from Flat Creek 4.8 miles upstream from Hoback	938.9	13,018,750	2,627 sm	1975-present	Max 30, 200 cfs June 11, 1997 Min 690 cfs Jan. 19, 1988.
Snake River Above Palisades Reservoir, Near Alpine, WY [1]	0.3 miles downstream from Wolf Creek 6.4 miles upstream from Greys River, 7.4 miles east of Alpine 16.1 miles upstream from Palisades	917.5	13,022,500	3,465 sm	1937-1939 1953-present	Max 38,600 cfs June 11, 1997 Min 740 cfs Nov. 16, 1955
Snake River At Moose, WY [1]	0.2 miles east of Grand Teton National Park Headquarters Visitor Center at Moose 0.3 miles west of U.S. Highway 191		13,013,650	Not Determined	1995-present	
Gros Ventre River At Zenith, WY	0.5 miles southwest of Jackson Hole Country Club 5.5 miles north of Jackson, WY		13,015,000	683 sm	1917-1918 (monthly) 1987-present	Max 6,170 cfs June 6, 1997 Zero flow on many days Affected by diversion

(1) Gage is regulated by Jackson Lake.
(2) June 1894 was considerable higher.
(3) Estimated by Walla Walla District.

The USGS gage designated Snake River Near Wilson, Wyoming, was operated for 3 years during the period October 1972 to September 1975. The gage was located near the Jackson-Wilson Bridge at RM 951. Given its location relative to the Federal levee system, the station period of record has been extended through correlation with other nearby gaging locations to cover the entire period 1904 to the present. A correlation for the 1894 historical peak was also determined. Various drainage areas for the Wilson gage have been published over the years. The USGS determined the drainage area to be 2,342 square miles and carried this value in their annual stream flow listings. Based on this value, one can also determine that the Snake River

above the Gros Ventre River confluence has a drainage area of about 1,700 square miles. However, the Walla Walla District and other agencies had approximated the drainage area for the Wilson gage at 2,500 square miles prior to the 1970's. Based on the 2,500 square miles value, the Snake River drainage area above the Gros Ventre River confluence was determined as 1,878 square miles.

Due to the convenient location of the Snake River Near Wilson USGS gage, both regulated and unregulated annual peak discharges have been determined for this station for the period from 1904 until the Wilson gage was established in 1972. Unregulated (natural) peaks were computed by determining what the flood peaks would have been naturally without flood control operations and irrigation storage at Jackson Lake. For years when the gage was not operated, estimations of regulated peak discharges were made based on the records of relatively nearby USGS gaging stations, and from estimated or gaged spot flow measurements on tributary streams.

The Wilson gage was discontinued in 1975, and a new gage was established about 13 miles downstream at a location below Flat Creek where channel geometry was more stable. Although there are a number of small tributaries entering the Snake River downstream, including Flat Creek, the peak flow data from the new gage location has generally been used, without adjustment, for the Wilson area. In addition to the computed period of record (1904 to present), an estimate of the 1894 flood peak was made for the Wilson location based on correlation with records for the Snake River at Idaho Falls, Idaho, gage location. The 1894 flood was the largest in recent history for streams in the Northwest, disregarding the 1927 flood resulting from the Lower Slide Lake failure.

In summary, the flows in the study area were based on a composite record developed using correlation with other gages from 1904 through1972, the actual record at Wilson from 1972 through 1975, and the actual record below Flat Creek from 1975 to the present. Floods exceeding 10,000 cfs occurred 83 times between 1904 and 1988, and discharges exceeding 20,000 cfs have occurred 15 times. Major floods resulting from normal snowmelt are indicated in Table 3.2 (estimated annual peak discharges).

Table 3.2 - Major Flood Peaks for Composite Record at Wilson, WY			
Year	**Peak Flow (cfs)**	**Year**	**Peak Flow (cfs)**
1894	41,000	1927	22,900 (1)
1918	32,500 (1)	1943	22,800 (1)
1997	32,000 (2)	1911	21,900 (1)
1904	28,500	1982	21,800 (1)
1909	25,900 (1)	1913	21,200 (1)
1986	25,600 (1)	1914	20,700 (1)
1996	24,800 (1)	1928	20,700 (1)
1917	23,400 (1)	1912	20,200 (1)

(1) Flows partially regulated by Jackson Lake Dam.
(2) An unofficial reading of 32,027 was observed on this date. The official USGS data lists only the mean daily value of 30,200 cfs.

The Snake River frequency curves at Wilson, Wyoming were previously analyzed by the Walla Walla District in 1975. The additional data now available has been added to the previous data in computing new curves used for the current *Feasibility Study*. The approach applied to the analyses of the unregulated (natural) discharge frequency curves is similar in both instances. The present analysis was based on 83 years of systematic recording (1904-87) extended to include the 1894 historical peak (41,000 cfs). A log Pearson Type III curve was fit to the data using an adopted skew coefficient of -0.2. Only the regulated peak discharge frequencies were recalculated in 1987 for the Snake River study reach above the Gros Ventre confluence. Peak flood discharges for selected recurrence intervals at this and other locations are listed in tabular form on Table 3.3

Table 3.3 - Natural and Regulated Discharge- Frequency Relations						
Exceedance Probability	**Average Recurrence Interval (years)**	**Snake River Above Gros Ventre (1)**		**Gros Ventre Near Kelly (2)**	**Snake River Near Jackson (3)**	
		Natural (cfs)	**Regulated (cfs)**	**Natural (cfs)**	**Natural (cfs)**	**Regulated (cfs)**
50	2	15,700	12,000	2,900	19,700	14,600
20	5	20,200	15,300	3,90	25,200	18,800
10	10	22,900	17,200	4,600	28,600	21,300
4	25	26,200	19,500	5,400	32,600	24,400
2	50	28,400	21,200	6,000	35,500	26,700
1	100	30,500	22,900	6,600	38,200	28,600
0.2	500	36,600	36,600	7,900	44,300	44,300

(1) Natural peak flow data for the Snake River above the Gros Ventre River confluence is derived form Walla Walla District frequency curves dated February 1975. Regulated peak flow data is derived from Walla Walla District frequency curve data dated July 1987.
(2) Natural peak flow data for the Gros Ventre River near Kelly is derived form Walla Walla District frequency curves dated September 1986.
(3) Natural and regulated peak flow data for the Snake River below the Gros Ventre River confluence is derived form Walla Walla District frequency curves data dated June 1987.

3.1.2.3 Water-Surface Profiles

Hydraulic modeling of the Snake River in each of the four selected study areas was performed using HEC-2, a computer backwater model developed by the U.S. Army Hydrological Engineering Center (HEC). Most of the proposed channel modifications would fall within the regulatory floodway as delineated by the Federal Emergency Management Agency in their May 4, 1989 Teton County Flood Insurance Study. The area is designated as a no-rise area which means that actions within or adjacent to the floodway should not result in a rise in the regulatory, 100-year floodwater-surface profile.

Mathematical modeling of this river is very difficult. The flow pattern is braided; the channel bed is constantly changing; and the river does not flow in the same channel from year to year. Gravel bars and accumulations of debris can cause local variations in the water surface. At certain levels, a very small change in the trial water surface results in a very large change in the surface area covered by the water. Due to these and other similar problems, a high degree of reliance should not be placed on the results of the mathematical analysis. Discrepancies of up to 2 feet can be expected in some areas, and a difference of up to 4 feet has occasionally been found

in areas where major channel changes have occurred or where divided flow exists. Since the river is constantly changing, the modeling results represent, at best, conditions at one point in time.

The model was calibrated to high-water marks, which were observed during the 1997 peak flood. During the 1997 flood, a peak flow of 32,027 cfs was observed at the USGS gage Snake River below Flat Creek. The results of the hydraulic analysis at each alternative site are indicated in Appendix B, Hydrology. Considering the aforementioned limitations, the HEC-2 models provided a reasonably good fit to the observed high-water marks and a thus provide a usable base for comparing the effects of proposed alternatives on the flood elevations.

3.1.2.4 Erosion and Sedimentation

Flow velocities in both the main channels and the secondary channels of the Snake River tend to be high, due to the general steepness of the valley. As a result the channel-bed complex is constantly changing. During high flows, avulsion of the main channel into side channels is common. When the flow erodes a gravel bar or the main channel becomes clogged with debris, the flow can shift direction suddenly and unpredictably.

Construction of the Federal and non-Federal levees along the Snake River blocked the lateral spread of the river and reduced the width of the floodplain and the degree of randomness of the braided system. This limited the ability of the channel to migrate and restricted avulsion activity to the area between the levees, concentrating flows in the existing main channels and increasing the frequency of attack on islands and vegetation between the levees. Bedload materials, brought into suspension by the turbulent flow, are more likely to be carried through the system rather than to be carried laterally into the slower secondary channels where they could be redeposited over a wider area of the floodplain.

Historical channel changes and erosion that has occurred in the past, were documented based on available aerial photographs of the area, some dating back to 1944. Photographs were reproduced at the same scale and overlaid to produce a record of the progressive erosion of vegetated islands and shoreline between 1944 and the present (Appendix B, Hydrology). Based on the photographs it was also possible to roughly estimate changes in the active meander belt area and channel length. The analysis provided information on erosional trends, level of

instability of each area, characteristic overflow routes, and meander magnitude and length. The photographs generally indicate that the vegetated islands have been progressively reduced in size or eliminated altogether between 1945 and the present. In their place, the river has left a broad active channel confined between the levees in which the bedload is constantly reworked. This constant churning has removed the finer material and thus leaves behind a bed that is predominantly in the gravel and cobble classes [2 millimeters (mm) through 256 mm] In parts of the study reach, half the bedload is in the cobble range (64 mm or 2.5 inches and above).

Historical bed elevation changes were determined for a 33-year period (1954-88) based on a series of sediment ranges (surveyed cross sections) established throughout the Federal leveed reach. The ranges were surveyed in 1954, 1967, 1973, and 1988. The vertical change in the thalweg and the average vertical bed change in the bed were determined along a larger reach that includes the study reach. Detailed results are shown in Appendix B, Hydrology.

Over the period of measurement, the surveys revealed a pattern in which areas of aggradation and degradation tended to be the opposite in several critical areas such as near the upstream and downstream ends of the levees and upstream of the Jackson-Wilson Bridge and the Gros Ventre confluence. The final 15-year period (1973-88) again exhibited a tendency toward alternate areas of erosion and degradation in a pattern nearly opposite to the previous period. Alternating areas of erosion and deposition are probably characteristic of the random nature of the process in a braided stream. Over-plots of successive range surveys indicate that a considerable amount of material was moved laterally during major channel shifts. A large part of the material eroded at one loop in the river was probably redeposited as a point bar on the inside of the next loop downstream. The average of erosion and deposition from 1954 through 1988 is shown in Plate 10.

The net volume of erosion during the 33-year period was heavily influenced by greater erosion in the early years (1954-67) following the completion of the levees. To an unknown extent, material borrowed from the riverbed during levee construction also contributed to the calculated losses. In the periods between 1967 through1973, and 1973 through 1988, losses tapered off gradually and then dropped off sharply. Measurements from more recent (and more limited) surveys taken in 1996 indicate that considerable sediment movement has occurred since the last complete survey in 1988. In Area 10, for instance, the 1996 survey indicated that more than 400,000 cubic yards of material may have been lost in this area alone since 1988. The flood of

1997, which peaked at the highest flow since 1918, probably moved a considerable amount of gravel and rearranged the channel-bed geometry.

Comparison of post-levee profiles and pre-levee profiles indicates that the greatest erosion has occurred where the levees had the greatest impact on the pre-project flow patterns during flood conditions. For instance, the area of deposition upstream of the Gros Ventre River corresponds to an area where no levees exist on the left side of the river, and levees on the right generally follow the active meander boundary. Downstream of the Gros Ventre, where the heaviest erosion took place, levees crowd the river to the east cutting off about one-half of the active meander belt width.

Determination of the amount of sediment that is transported through the study reach on an average year and during a major flood event would have been useful information. Unfortunately sediment transport and deposition on this reach of the river is very complex and difficult to determine. During a major flood, the flow is spread across a braided channel system that may look more like the teeth of a saw than a typical channel section. Along the same cross section there may be one or more areas of flow concentration where velocities reaching 10 to 12 feet per second (fps). There are secondary currents that may be moving at 3 to 4 fps, and intermediate areas of shallow overflow, where velocities are anywhere from 0.5 to 3 fps. Sediment is likely to be eroded from one bar exposed to a high-velocity current, then be redeposited a short distance downstream where the flow escapes over the side of the channel. Local residents have reported watching the current shift from the levee on one side of the river to the levee on the other in a matter of hours.

As part of this *Feasibility Study*, attempts were made to estimate the quantity of sediment that could be transported by the river in an average year by first calculating the initial transport capacity, and then running an HEC-6 computer simulation for an extended period of time to determine the equilibrium transport rate. Widely varying values were calculated depending on the formula used and the reach of the river being used as a transport reach. Numerous runs were also made in an attempt to determine the pattern of erosion and deposition with and without the restoration features for a typical year and for a period of 6 years in the future. Although a reasonable pattern was achieved on some trials the model was far too unstable to be considered reliable.

Due to the complexity of the flow patterns and lack of confinement of the flow, it does not appear possible to accurately model the sediment transport of the study reach with a mathematical model. A two-dimensional model would reproduce the instantaneous velocity distribution better. However, due to the channel complexity, and major channel boundary changes, it is unlikely that it would be successful. Although considerable effort was expended on this portion of the study, the results of the mathematical analysis did not appear to be accurate enough to justify the time and space required to include them in this report. Experience obtained by monitoring the proposed project and observing the effect of various restoration measures will likely provide a much better indication of system response than could be obtained with any modeling effort.

3.1.2.5 Flooding

Flood characteristics of the Snake River are typical of a highly braided stream. Due to the high transport of bedload the channel-bed complex is constantly changing. During high flows, avulsion of the main channel into side channels is common. When the flow erodes a gravel bar or the main channel becomes clogged with debris, the flow can shift direction suddenly and unpredictably. Flow velocities in both the main channels and the back channels tend to be high due to the general steepness of the valley. Flood damages include water damage from inundation, loss of land due to bank erosion, and damage to levees due to erosion or undercutting. Before the levees were constructed, flood damages in unleveed reaches began at flows of 5,000 cfs and became significant as flows increased to the 8,000 cfs to 10,000 cfs range. With the current levee system in place, significant damage now begins in the non-Federal reaches with flows in the range of 11,000 cfs. However, bank materials are often so low in resistance that erosion can continue, to some extent, even during low flows.

3.1.2.6 Existing Levee System

A system of levees was established in the lower reaches of the Snake and Gros Ventre Rivers to minimize flooding, confine lateral channel migration, and prevent bank, channel, and floodplain erosion (see Plate 5). The Federal project begins 4 miles below the Snake River Bridge near Moose, Wyoming, and ends about 4 miles below the Jackson-Wilson Bridge. Construction began in 1957 and was completed in 1964. Over the years, an array of non-Federal levees were

constructed outside of the limits of the Federal project, each to address a separate problem area. Construction was variously accomplished by local, State, and Federal agencies, sometimes with private assistance.

The federally constructed project provides continuous levees on the right bank of the Snake River between RM 961.0 and RM 947.6. On the left bank, the levees begin at RM 961.8 and end at RM 947.6, with a break between RM 957.2 and RM 952.8. The break is in the vicinity of the Gros Ventre confluence in a reach with a narrow floodplain left of the main channel, and includes Area 10. The levees act to: restrict lateral channel migration; confine floodwaters to a narrow, but relatively deep cross-sectional area; and reduce channel aggradation by improving movement of sediment load. The levees reduce the typical flooding zone within which channels migrate from 5,000 to 8,000 feet down to 1,000 to 2,000 feet. The levees are typically earthen and gravel fill constructs. The top width is 10 feet, the back slope is 2 to1, and the front slope is a combination slope with 2 to1 near the toe and 4 to 1 near the top (see Plate 6). The levee toe and the lower part of the front slope are protected by dumped stone up to a given flow level.

Many of the existing levees were constructed in response to perceived threats arising from avulsion of the main channel. As an example, there was great concern in the 1940's and 1950's that the Snake River was tending westward, posing a major threat to the town of Wilson and upstream developments. There has also been continuing concern that the river could eventually capture the lower reaches of Fish and Flat Creeks. Capture of Fish Creek is prevented as long as the Federal levees are adequately maintained. Capture of Flat Creek would harm the elk habitat area, damage spawning channels, and also endanger the Highway 26 Bridge. In the vicinity of the Gros Ventre River confluence, avulsion of both the Snake River and Gros Ventre River main channels is endangering spawning channels in the Three Channel Spring Creek study area. Bank erosion and channel scour was particularly evident following the 1986 flood. Extensive levee repairs were required during and after that flood, and, in addition, Teton County requested assistance for clearing and snagging operations in the main channels of both the Snake and the Gros Ventre Rivers. In response, a Federally funded, low-level clearing and snagging project was completed in the fall of 1989.

HEC-2 modeling accomplished for previous floodplain studies have indicated that flow velocities, averaged across the channel, during 100-year flood events vary from 2 to 11 feet per second (fps) on the Snake River studied reaches and from 4 to 9 fps on the Gros Ventre River studied reaches. Field observers have noted that local velocities were much higher at points

affected by log jams, flow over riffles and rapids, and at levee impingement points. The majority of the damage to the levee sections often appears to occur during the recession from the flow peak. It is likely that high flows, which override the gravel bars and low-flow meander loops, leave the channel bed clogged with debris and gravel. As the water level drops, the flow follows the path of least resistance where it may be directed against undisturbed land along the bankline. The flow may back up on one side of the channel, then flow rapidly down a steep incline toward the opposite side of the channel. These impinging flows can reach very high velocities, undermining trees, damaging or undercutting levee protection, and resulting in high levels of bank erosion in non-leveed reaches.

Velocity profiles taken during the May-June 1974 flood event (discharge of 13,790 cfs) estimated that high intensity impingement flows (of up to 10 fps) affected on the order of 5 to 10 percent of the Federal project levee length. During the 1991 runoff season the Corps Waterways Experiment Station collected water-surface profile data and measured impinging velocities at 8 different locations within the Federal project reach. Flows during this period varied from 14,000 to 16,000 cfs, which correspond to a 2- to 3-year peak flow event. It should be noted that the high velocities resulted from the flow escaping from a high point on one side and then accelerating across the channel to a low point on the other, where it impinged on the levee embankment. Results indicated that depth-averaged velocities could reach 12 fps in the impingement zone near the levees, and point velocities farther out could occasionally reach 16 fps. Velocities of 8 to 10 fps within 2 or 3 feet of the riprap face were very common at impingement locations. Scour depths of up to 15 feet below the water surface were measured in some locations.

3.1.2.7 Jackson Dam Operation

Nearly all of the large natural lakes in the area were formed behind the terminal moraines left by prehistoric glaciers. Jackson Lake, located on the Snake River 38 miles upstream from the city of Jackson, is, by far, the largest of these natural bodies of water, with a volume of 847,000 acre-feet, a depth of over 400 feet, and a length of 20 miles. Outwash from the large glacier at the Jackson Lake location, smaller nearby glaciers, and sediment from tributary streams is distributed downstream, forming a steeply sloping valley floor. Variations in vegetation, as seen on aerial photographs downstream of Jackson Dam, clearly show the patterns of a highly-braided flow that probably extended across the entire width of the valley during glacial recession.

Similar patterns can still be seen in outwash from receding glaciers in the Columbia Icefields of Canada.

Outflow from Jackson Lake escapes around the eastern side of the terminal moraine at the present location of Jackson Dam. Episodes of meander belt widening and channel down-cutting have left several terrace levels stepping down to the present active channel bed. The channel entrenchment reaches a maximum depth of about 160 feet near Deadman's Bar (about 16 miles downstream of Jackson Lake Dam). The depth of entrenchment decreases and the width of the floodplain increases as one moves farther downstream. Finally, somewhere in the vicinity of the Gros Ventre River, the terraces disappear and the channel emerges on the surface of the valley. Numerous relic channels and secondary branches can be seen in aerial photographs. These often become active during high-flow periods, allowing flood flows to escape the main Snake River channel and fan out across the valley floor.

Reservoir levels at Jackson Lake have been regulated to maintain optimum breeding and nursery conditions for recreational fisheries (*e.g.*, Mackinaw Lake Trout) to the exclusion of native river species downstream. This has usually meant holding the pool elevation constant from October 1, the end of irrigation season and approximately the middle of Mackinaw egg-laying season, until the eggs hatch in the spring. However, recognizing river cutthroat trout as an important resource, fisheries managers have determined that a minimum stream flow of 280 cfs from Jackson Lake is required to support a healthy population of river cutthroat trout. The optimum flow is 400 cfs, and flows above 600 cfs should be avoided. To implement this plan, the lake can be drawn down as much as 5 feet after October 1 to maintain stream flows below the dam. There is an attempt to meet the 280 cfs minimum, but no formal minimum release requirement exists. The USBR *Operations Manual*, dated December 1997, states in part: "If the reservoir was drawn down to the minimum flood control space on October 1 then the release is set to match inflow. If the reservoir was drawn down below the minimum flood control space on October 1 then the release can be set to a minimum of inflow or 280 cfs whichever is less. The release selected will allow the reservoir to either refill to the minimum flood control space gradually over the winter or refill as much as possible up to the minimum flood control space."

Without Jackson Lake Dam, flows would have dipped below 400 cfs in each of the last 87 years and dropped below 280 cfs in 74 of those years. Statistically, stream flows have been less than 400 cfs 21.1 percent of the time and below 280 cfs for 5.5 percent of the time. With Jackson Lake Dam in place, there were 9 years since 1909 with average annual flows less than 1,000 cfs.

The lowest year was 1977 with an average annual flow of 660 cfs. If flows above 4,000 cfs are excluded because they occurred during floods and may not have been held by a moderate size dam, then there were 15 years with average annual flows less than 1,000 cfs. Of these, 6 occurred as back-to-back pairs. Again, the lowest average annual flow was 660 cfs in 1977.

During the construction of Palisades Dam in 1956, the Corps negotiated 800,000 acre-feet of nonexclusive flood control storage at the two projects with 25 percent coming from Jackson Lake and 75 percent coming from Palisades Dam. The agreement requires the USBR to make the storage available between March 1 and May 1 each year unless the Corps and the USBR agree in advance that expected spring runoff would be better controlled by a different operation. Although snowmelt forecasting has come a long way, the exact timing and quantity of runoff is still subject to considerable error. The 1997 spring runoff was nearly 50 percent greater than anticipated, forcing both dams into defensive operation and causing severe flooding downstream.

For the current *Feasibility Study*, a representative sample of flow periods was selected that reflect current operating needs of downstream irrigators as interpreted by the USBR Reservoir Operations Center. Both 1992 and 1994 were classic low-flow years. The 5-year period extending from October 1991 through September 1996 appeared to provide a full range of possibilities including the 2 drought years of 1992 and 1994 as well as an unusually high runoff year in 1996. Assuming reasonable forecasting, volume becomes a more important indicator of low-flow capability than peak flow. Not surprisingly, irrigation demands are higher in low-flow years than in normal years due to dry conditions everywhere else in the basin. The basin runoff volume for 1994 was the sixth lowest flow on record, and followed only 1 year behind 1992, which was the fifth lowest flow on record. Being recent in history and very low, 1994 was chosen as the test case for low-flow discharge. Irrigation demands in 1992 were considered too extreme for the present analysis.

The HEC's model, HEC-5, Simulation of Flood Control and Conservation Systems, was used to route the flows through Jackson Lake. The following criteria were used for annual flow routing:

- Maintain a minimum flow of 400 cfs below the dam.
- Maintain minimum irrigation flows at Jackson-Wilson Bridge equal to 1994.
- Draw Jackson Lake down to elevation 6,755 by October 10.
- Do not exceed 15,000 cfs at Jackson-Wilson Bridge.
- Repeat the 1994 irrigation demand curve during each year of the simulation.

This analysis indicated that the 400-cfs minimum could be maintained during the winter if irrigation demand was the same each year. In the draught year of 1992 the irrigation demand was considerably higher than normal, resulting in an October 1 pool level that was several feet lower than would normally occur at this time of the year. It was so low that it would not have been possible to refill the reservoir if 400 cfs had been released during the fall and winter months. Based on the analysis to date, it appears that the 400 cfs could be maintained during normal flow years, but that during drought years similar to 1992, this level of release could not be achieved while still meeting the irrigation demands for the following year. It should be emphasized that the USBR operates Jackson Dam. They are in a better position to consider all of the operational constraints, and should be the agency that makes the final determination whether additional winter flow augmentation is possible

3.1.2.8 Groundwater

In addition to surface sources of water, considerable amounts of groundwater drain into the Snake River in Jackson Hole. The porous and unconsolidated alluvial and glacial deposits are the major aquifers in Teton County. Much of the floodplain is close to the level of the river and laced with abandoned or relief channels. Due to the ready exchange of water between the river and the aquifer, channels that have been abandoned or cut off by levees often still contain flowing or standing water. Along the Snake River and its major tributaries the aquifer can supply very large amounts of water. Water tables are often less than 5 feet below the ground surface for a significant portion of the year. Groundwater levels, reflecting the surface runoff patterns, are highest in the spring and early summer and lowest later in the fall and early winter. Local authorities and Walla Walla District construction personnel report that spring-fed water courses will rise in tandem with the snowmelt runoff in the main streams, but the increase in flow is of a much lesser magnitude and does not seem to approach damaging levels.

In the early 1990's concerns were raised by residents in the west bank area of the Snake River. At that time, there was basically no documentation of groundwater elevations in the area. The Wyoming State Engineers Office and the Teton County Commission initiated the Observation Well System north off Highway 22 and west of the Snake River channel that included 30 wells. Additionally, the Teton County Resource District through a cooperative arrangement with the USGS installed a surface water gaging system. The Wyoming State Engineer's Office, Surface Water Division installed a more expanded gaging system that monitored additional stream sites

as well as irrigation diversions. In 1997, the Wyoming State Engineer's Office, Ground Water Division, in cooperation with the Teton County Commission installed an additional 12 observation wells south of Highway 22 and west of the Snake River channel. This completed the system as it exists today with the exception of the 8 reference wells located along the east bank of the river, bringing the total number of wells up to 50.

Due to the infancy of the groundwater and surface water monitoring systems, there are no conclusions to be drawn at this point in the study. Appendix C, Groundwater, contains data that has been collected as part of a database that will be completed in the future. As the restoration effort continues, the existing monitoring system will prove to be a valuable tool for tracking what affects (if any) the restoration measures will have on the state of Wyoming water resource.

3.1.3 Environmental Resources

The existing conditions assessment of environmental resources are summarized below in the following sections: Aquatic Ecology, Terrestrial Ecology, and Threatened and Endangered Species.

3.1.3.1 Aquatic Ecology

The Snake River and tributary streams in the study area provide an environment for a wide variety of aquatic species including invertebrates, plants, and fish. Aquatic invertebrates are a major food source for all carnivorous fish in the Snake River and a wide variety including mayflies, true flies, caddisflies and stoneflies are present. Most are herbivores and detrivores although a few are carnivores.

True aquatic plant communities are supported by standing or flowing water year round and are composed of white buttercups (*Ranunculus* spp.), speedwell, waterweed, pondweed, and watercress. Mat-forming algae are common in shallow stagnant ponds, and liverwort and stonewart species are also common. The cobble-gravel bottom communities are dominated by foxtail, silverberry, willow, timothy, sedge, muhlenbergia, sweet clover, horsetail, and dock. Aquatic plants, particularly algae, supply a major food source to aquatic invertebrates and to primary consumers such as suckers.

The Snake River in much of the study area is designated as a Class 1 or blue-ribbon trout stream by the WGFD. This designation indicates that the river is of national importance as a trout stream and warrants the highest priority for protection. The fine-spotted cutthroat trout is the key aquatic species to be considered in the mitigation study and planning process. Among the many game and nongame fish species present in the region , the indigenous Snake River fine-spotted cutthroat trout is economically the most important species, as it is the major game fish captured by fishermen in the Snake River. The Snake River fine-spotted cutthroat trout is a self-sustaining (naturally reproducing) subspecies found only in the Snake River drainage from the Palisades Reservoir in Idaho, upstream to the headwaters in Yellowstone National Park. This wild stock maintains its current population by spawning in suitable habitat, regionally known as "spring creeks," without stocking of juvenile or adult fish to the river system. This trout supplies the major sport fishery in the Snake River, from Jackson Lake Dam down to the canyon area of the Snake River above Palisades Reservoir.

Spawning, rearing, and overwintering habitat are considered to be the major limiting factors for cutthroat trout in the study area. Most cutthroat trout spawning occurs during the period from March through June in the spring creeks that enter the river along the study reach. Openings to many of these spring creeks are currently blocked by levees. Little or no spawning habitat exists in the main river for a number of reasons. These include large sediment bedloads and turbidity in the springtime flows (during the spawning period), human induced modifications to the channel, and a cobble substrate that is typically too large for cutthroat spawning. Sloughs and side channels are important sources of rearing and overwintering habitat, particularly for young age classes of cutthroat trout.

Other trout species found in this region of the river are less abundant. They include brook, rainbow, brown, and lake trout (which may pass through Jackson Lake Dam), and possibly grayling.. Another game species that is apparently abundant but little utilized by fisherman is mountain whitefish. An increased amount of overwintering habitat would also be used by these species. The overall population distribution is not expected to change with features proposed in the *Feasibility Study*. Construction, maintenance, and long-term effects for these game fish species would be similar to the effects on cutthroat trout.

Nongame fish species present include suckers (an important food source for bald eagles), five species of the minnow family, with Utah suckers and Bonneville redside shiners most abundant,. and sculpins. Small fish may be used as prey by cutthroat trout.

Levee construction and other human activities have led to significant decreases in the amount and quality of spawning, rearing, and overwintering habitat for aquatic species . Increases in these resource types will be needed to promote the future viability of the game and nongame fish.

3.1.3.2 Terrestrial Ecology

a. Vegetation. The vegetation in the upper Snake River drainage near Jackson, Wyoming, is typical of the central Rocky Mountain region. Upland vegetation types in the area include sagebrush-grassland, lodgepole pine/Douglas fir, and subalpine fir/Engleman spruce . The sagebrush-grassland type occurs on the glacial outwash plains and terraces above the floodplain. This type is dominated by sagebrush and perennial grasses, *e.g.*, wheatgrasses, fescues, and bluegrasses. Forests dominated by lodgepole pine occur at lower elevations (6,300 to 7,800 feet) along rivers and above the glacial outwash plain. Douglas fir intermixes with lodgepole pine, but is generally dominant only on ridge tops and east-facing slopes. Subalpine fir and Engleman spruce dominate higher elevation (7,800 to 10,000 feet) forests.

The floodplain along the Snake River and its tributaries includes mixed deciduous/coniferous forests and wetlands. Floodplain forest consists of narrow-leaf cottonwood and willow intermixed with Engleman and blue spruce. Wetlands occur where the water table is high enough to support hydrophytic plants, *i.e.*, plant species that grow in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content. These include three major types: palustrine shrub-scrub, palustrine emergent, and aquatic bed. The palustrine shrub-scrub wetlands are found primarily on stable gravel bars and dikes and are dominated by willow and mountain alder. Sedges, cattails, and bulrush are the primary species in palustrine emergent wetlands. The dominant species in aquatic bed wetlands depend on bottom substrate. Aquatic beds along shorelines tend to support watercress. Pondweed is common in streams or ponds with silt bottoms and ballhead waterleaf occurs in rocky substrates.

The study area was once characterized by an abundance of diverse riparian vegetative habitats. Wooded islands, transitioning to riparian and wetland communities were a vital component of the highly productive braided-channel riverine environment. Construction of the levee system through most of the study reach has resulted in erosion, degradation, and in many cases destruction of these island habitats.

b. Mammals. The Jackson Hole, Wyoming, area is known for its diverse wildlife in the valley and surrounding mountains. Mammals such as elk, mule deer, moose, bighorn sheep, and American bison are the most prominent wildlife in the Jackson Hole area. Aquatic furbearers, black bear, wolf, coyote, and a variety of small and medium-sized mammals also occur. Big game concerns focus on usage patterns within the region of Jackson Hole. Important winter feeding areas are located near the work area and migration patterns to and from these feeding areas go through the Snake River drainage. The usage patterns include spring-summer-fall range, winter range, winter/year-long range, critical winter range, and critical winter/year-long range. The local mule deer, elk, moose, and bighorn sheep herds represent these types of usage.

Jackson Hole and the surrounding mountains provide about 1,000 square miles of summer range for approximately 15,000 elk. The National Elk Refuge to the northeast provides about 24,000 acres of winter habitat for 10,000 elk. The WGFD classifies this refuge as a crucial winter range, which is defined as one that determines whether the elk population in the area reproduces and maintains itself at or above WGFD target levels. The Jackson Hole area provides migratory habitat for mule deer throughout the year. The upper Snake River drainage provides year-round habitat for about 200 to 300 moose. During the winter, an additional 400 to 500 moose from the surrounding uplands migrate into the river bottom area. Bighorn sheep are present seasonally in all major drainages within the Snake River and Gros Ventre River Basins.

Smaller mammals including shrews and voles are common in riparian areas along the Snake River and its tributaries. Aquatic furbearers such as beaver, mink, and muskrat are commonly seen in streams, ponds, and backwater areas along the Snake River near Jackson, Wyoming. The levees are generally too rocky or exposed to provide habitat for either the beaver or muskrat. Additional species include the river otter and the hoary bat (both of which are considered rare in Wyoming), the silver-haired bat, and the long-eared myotis. The wolverine and lynx, also rare, occur in the region.

c. Birds. The upper Snake River drainage provides habitat for a wide variety of resident and migratory birds, including waterfowl, raptors, and passerines. Approximately 150 different species have been observed, and 119 are documented or expected to breed in the area. The wetlands, ponds, backwater, and tributary creeks in the Snake River floodplain provide habitat for waterfowl and waterbird spring/fall staging, breeding, nesting, brood rearing, and wintering. The most prominent birds include Canada geese, trumpeter swans (a candidate for Federal listing as threatened or endangered), and sandhill cranes. Detailed information on resident populations

of these birds is provided in the Environmental Assessment. Dabbling and diving ducks winter on the river between Moose Junction and South Park and between the Jackson-Wilson and South Park Bridges. Winter duck densities frequently average 139 per mile of river and tributary. Other birds known to commonly occur in the Snake River floodplain near the Jackson Hole area include the loggerhead shrike, black-backed woodpecker, killdeer, tree swallow, yellow-headed blackbird, common nighthawk, belted kingfisher, and Wilson's warbler.

d. Raptors. The high numbers of fish and small mammals provide prey for a variety of raptors. The most commonly observed raptors are eagles, falcons, osprey, hawks, and owls. Most nest in trees behind the levees.

e. Amphibians and Reptiles. Relatively little is known about amphibians and reptiles in the Jackson Hole area. Two frog species, the spotted frog, and northern leopard frog, and one toad species, the boreal western toad, considered very rare or rare in Wyoming, have been documented in the vicinity of the proposed restoration project areas. The sagebrush lizard and western terrestrial garter snake are probably two of the most common reptiles in the area. These two species could be present in the existing riparian vegetation within or near the proposed environmental restoration work.

3.1.3.3 Threatened and Endangered Species

Over 30 rare plant species tracked by the Wyoming Natural Diversity Database occur in the vicinity of Jackson Hole levees. None of these species are Federally listed or proposed as threatened or endangered, but three are protected on U.S. National Forest Service (USFS) lands. It is highly unlikely any of these species occur within the proposed restoration areas between the levees. The USFWS has documented five animal species in the Jackson Hole area that are classified as threatened or endangered. Endangered species observed in this area include the bald eagle (*Haliaeetus leucocephalus*), whooping crane (*Grus americana*), and peregrine falcon (*Falco peregrinus*). The Jackson Hole area is also within historical range for the grizzly bear (*Ursus arctos horribilis*), a threatened species, and gray wolf (*Canis lupus*), an endangered species.

a. Bald Eagle. The upper Snake River drainage provides year-round habitat for bald eagles. Nesting usually occurs between February 1 and August 15. The Snake River population unit,

which includes the Snake River in Wyoming, its tributaries, and Jackson Lake, consisted of 24 known breeding pairs in 1982. The Coordination Act Report received from the USFWS stated, "No work activity within 1 mile of any active nests would occur between February 1 and August 15." For this reason, work is only allowed within 1 mile of active nests (current year) between August 16 and January 31. Changes to this work window must have prior approval from the USFWS. Bald eagles are likely to be found in or near the proposed work area most of the year. The chances of the environmental restoration project having any impact on the bald eagle are minimal due to the timing of the active work. There would likely be no direct impacts (mortality, loss of nest, *etc.*) or long-term population impacts (reduced reproduction, *etc.*). There may be some minor displacement of foraging or roosting eagles.

b. Peregrine Falcon. Until recently, the peregrine falcon was considered extirpated from Wyoming. A recovery program was begun in 1980. Between 1980 and 1987, 153 peregrine falcons were released to hack sites (the term used for reintroduction sites) in Wyoming, primarily in Yellowstone National Park and in or near the National Elk Refuge. Approximately 80 to 83 percent of the released birds reached independence. The wetlands and streams along the Snake River south of the Jackson-Wilson Bridge support a variety of birds that are prey for peregrine falcons. This area is considered forage habitat for peregrine falcons and three to four adults and sub-adults have been observed in this region between 1982 and 1988. Peregrine falcons are expected to leave the area soon after nesting is complete. The timing of nesting is similar to that of the bald eagle. They could be in the area any time between February and August.

c. Whooping Crane. The whooping crane is one of the rarest birds in North America. Reintroduction efforts at Gray's Lake National Wildlife Refuge in Idaho have resulted in whooping cranes occupying habitat in western Wyoming since 1977. Whooping cranes are occasionally sighted in the Jackson Hole area, primarily along the Gros Ventre River, and do migrate through the area of Jackson Lake during early spring. There is a chance a whooping crane may stop along the river in the Jackson Hole area, especially if sandhill cranes are using the area.

d. Grizzly Bear. The historical range of the grizzly bear once included most of Western North America. Currently, only six areas in the United States, including Yellowstone and Grand Teton National Parks, support self-sustaining grizzly bear populations. The grizzly bear is a resident species to the area, primarily north of the Jackson Hole area, however, current management in

Wyoming by WGFD is to discourage grizzly bears from living in areas of human habitation. The last sighting of grizzly bears in the Jackson Hole area was in 1994.

e. Gray Wolf. The gray wolf historically populated all habitats in the Northern Hemisphere except tropical rain forests and deserts. Currently, the largest populations of wolves in the lower 48 states occur in northern Minnesota. Remnant populations are believed to exist in Wyoming, Washington, Idaho, Montana, Michigan, and Wisconsin. In the summer of 1992, a wolf was sighted in Yellowstone National Park, the first documented observation in over 20 years. Wolves have been sighted this year following the elk herds into the Jackson Hole area (WGFD 1998, USFWS 1998).

3.1.4 Human Environment

This section describes the existing conditions in the study area related to population, land use, land ownership, socioeconomics, recreation, cultural resources, transportation, and irrigation.

3.1.4.1 Population

Jackson, Wyoming is the only incorporated town in the Teton County, and provides typical commercial, service, and public facilities, however there are several unincorporated communities and numerous suburban and rural residential neighborhoods in the area. Major employers in the county, varying with the season, include the Jackson Hole Mountain Ski Resort, Grand Teton Lodge Company, St. John's Hospital, Snow King Resort, Grand Targhee Ski Resort, Grand Teton National Park and the Teton County School District. The 1990 census indicated a population of 4,472 people in the town of Jackson and 11,172 in the county for a total population of 15,644 permanent residents. The official estimated 1997 population is 6,052 in town and 14,200 in the county for a total of 20,252. The seasonal resident population is considerably higher than this value, probably at least double.

3.1.4.2 Land Use

Land use in Teton County is heavily influenced by land ownership patterns. Federal land in the county is used primarily for recreation, wilderness, wildlife management, and forestry. Private

land is primarily classified as agricultural, although the use of land for agricultural purposes has diminished over the years. Over the past few decades, land previously classified as agricultural has been converted to residential and other nonagricultural uses. The Federal government is the largest landowner (97 percent) in Teton County.

Table 3.4 - Partial List of Land Use in Teton County

Agency	Description/Name	Area (acres)
U.S. Forest Service	Bridger-Teton National Forest	1,096,000
U.S. Forest Service	Targhee National Forest	276,000
U.S. Forest Service	Shoshone National Forest	2,000
National Park Service	Grand Teton National Park	310,000
U.S. Fish and Wildlife Service	National Elk Refuge	24,000
U.S. Bureau of Reclamation	Jackson Dam	N/A (not available)
U.S. Bureau of Reclamation	Snake River Vicinity	9,000
State of Wyoming	School Trust and Resource Lands	10,000
Wyoming Game and Fish	Wildlife Habitat	2,000
State Trust		8,000
Private Property		75,000

Private property accounts for approximately 3 percent (75,000 acres) of Teton County. And privately owned lands in the county are concentrated on the valley floor of Jackson Hole south of Grand Teton National Park. Most of the private lands within Jackson Hole have not been intensively developed, although there has been rural-to-urban land conversion over approximately the past 3 decades. Ranching has declined considerably as an economic activity, but much of the former ranch land remains mainly in agricultural or woodland use.

3.1.4.3 Socioeconomics

The Snake River and its tributaries have been an important resource in the economic and social development of the Jackson Hole area. A study of the economic importance of fishing to Jackson Hole is, in effect, a study of two of the states most outstanding resources: (1) the Snake River and its system of associated smaller rivers and creeks, and (2) the cutthroat trout. Fishing activities create demands for goods and services. The Jackson Hole area has become the summer home and vacation home destination for a number of families since 1970. Expenditures by these

families in the Jackson Hole area, like tourist expenditures, represent a new demand for goods and services and a flow of new money into the local economy.

Local jobs maintained by the $143,000,000 output related to sports fishing, accounts for about 25 percent of the total employment of Teton County. This is based on statistics furnished by the Jackson Hole Economic Development Council Web site. Local nonfarm sales in 1997 were estimated at $583,000,000 based on sales tax receipts of $35,000,000 in this sector. The sales tax rate of 6 percent would indicate gross sales of $583,000,000. Approximately 18,500 workers generated this $583,000,000 in sales. This allows each worker to generate $31,600 sales per year. If the $143,000,000 sports fishing output and sales is maintained, 4,500 jobs would be enhanced in the area.

3.1.4.4 Recreation

The Snake River in the vicinity of the four project areas principally experiences recreational use from rafting and fishing. Some waterfowl hunting also occurs on the river. Levees along the four project areas are used for a variety of recreational purposes including walking, hiking, jogging, bicycling, cross-country skiing, horseback riding, bird watching, nature viewing, picnicking, and other similar uses. The levees also provide access for direct river use such as fishing and waterfowl hunting.

The majority of recreational use within the study areas occurs in Area 9 near the Jackson-Wilson Bridge which carries Highway 22. Recreational use at this site occurs year-round, with high use continuing into November. South Park National Elk Feedgrounds receives limited public recreational use, most of which occurs during summer as hiking and nature viewing. However recent improvements in pathways near the Elk Feedgrounds have resulted in increases in public recreational use. The southwest levee at Jackson-Wilson Bridge experiences considerable use. The northwest levee gets only limited use while the southeast levee does not get any use. The northeast levee gets a lot of use due to the close proximity of a park. Many private lands along the river carry recreational easements granted to the U.S. Bureau of Land Management (BLM). In general, boating, wading, hiking, picnicking, *etc*. are allowed while shooting, hunting, open fires, and camping are not allowed on the private land easement areas. In addition, all BLM lands are closed to camping.

Views of the floodplain, by boaters and other recreationists using the Snake River, are generally restricted because of adjacent riverbanks, levees, and vegetation. The primary views along the rivers are of the mountains, particularly the Grand Teton Mountains, which can be viewed beyond the riverbanks and levees in locations where there are openings in the riparian vegetation.

3.1.4.5 Cultural Resources

The area of the proposed environmental restoration project includes floodplain areas between the levees along the Snake River. A Class 2 reconnaissance survey was performed within the generalized environmental restoration project study areas during the period August 12 to 16, 1996, by the Walla Walla District's staff archaeologist. Record searches were also conducted. No previously unrecorded cultural properties were found during the reconnaissance survey. Record searches identified two previously recorded sites close to two of the proposed environmental restoration project areas, but outside of the levees. Because the previously recorded sites are located outside of the levees, away from where the proposed actions would occur, the Corps determined that the proposed environmental restoration project would have no effect on any previously listed cultural property. The Corps also determined the potential for the occurrence of any unrecorded cultural properties in the areas of impact to be low.

A copy of the Corps' Survey Report was forwarded to the Wyoming Division of Cultural Resources, State Historic Preservation Office (SHPO), for review and concurrence. In their letter of February 12, 1997, the SHPO responded that no sites meeting the criteria of eligibility for the National Register of Historic Places would be affected by the environmental restoration project. The SHPO recommended the project proceed in accordance with state and Federal laws, subject to the following stipulation: "If any cultural materials are discovered during construction, work in the area should halt immediately and the Corps and SHPO staff must be contacted. Work in the area may not resume until the materials have been evaluated and adequate measures for their protection have been taken."

3.1.4.6 Transportation

Several highway routes provide year-round transportation in the vicinity of the proposed environmental restoration project. The primary route used by north and southbound traffic is U.S. Highway 26 (Plates 1 through 4). The highway enters the Jackson Hole area from the northeast, continues through the valley and the community of Jackson and exits the valley to the south. Wyoming State Highway 22 starts on the west side of Jackson, crosses the Snake River at the Jackson-Wilson Bridge, and continues west over Teton Pass. Wyoming State Highway 390 extends north from its intersection with State Highway 22 near the Jackson-Wilson Bridge and is a primary route used by north and southbound traffic on the west side of the valley.

3.1.4.7 Irrigation

Numerous irrigation diversions exist off the Snake River and other major tributaries. Diversions can have significant impacts. As an example, during low water years, the total flow is diverted from the Gros Ventre River in late summer and fall, leaving the lower 3 miles down to the Snake River confluence dry, except for a small amount coming from groundwater springs and irrigation return flows.

The irrigation season generally lasts from about May 1 to October 1. There are currently eight active diversions within the Federal levee project area and an additional eight inactive diversions. Some of the diversion headworks serve more than one canal. The headworks are typically concrete with hand operated slide gates. Downstream of the Federal project levees, there is a major diversion behind the Upper Taylor Creek Levee, a major diversion through the Federal Levee Extension, and a minor diversion at the upstream State Game and Fish Levee. The two major diversions are for irrigation, and the minor one provides a dependable supply of water to a downstream spawning channel tributary to Flat Creek. There are no active diversions in the vicinity of the non-Federal levees along the lower reaches of the Gros Ventre River. However, there is a major diversion along the left bank of the Gros Ventre River just upstream of the Grand Teton National Park boundary. There is also a back channel on the right bank of the Gros Ventre River above the non-Federal levee area from which numerous diversions are made, including some into the country club and golf course developments.

Once Jackson Lake is filled by the spring runoff, Jackson Dam passes inflow. Releases above the level of inflow commence when required by those holding irrigation storage rights. In general, elevated flows last all summer and taper off to minimum releases in September or early October.

3.2 Future Without-Project Conditions

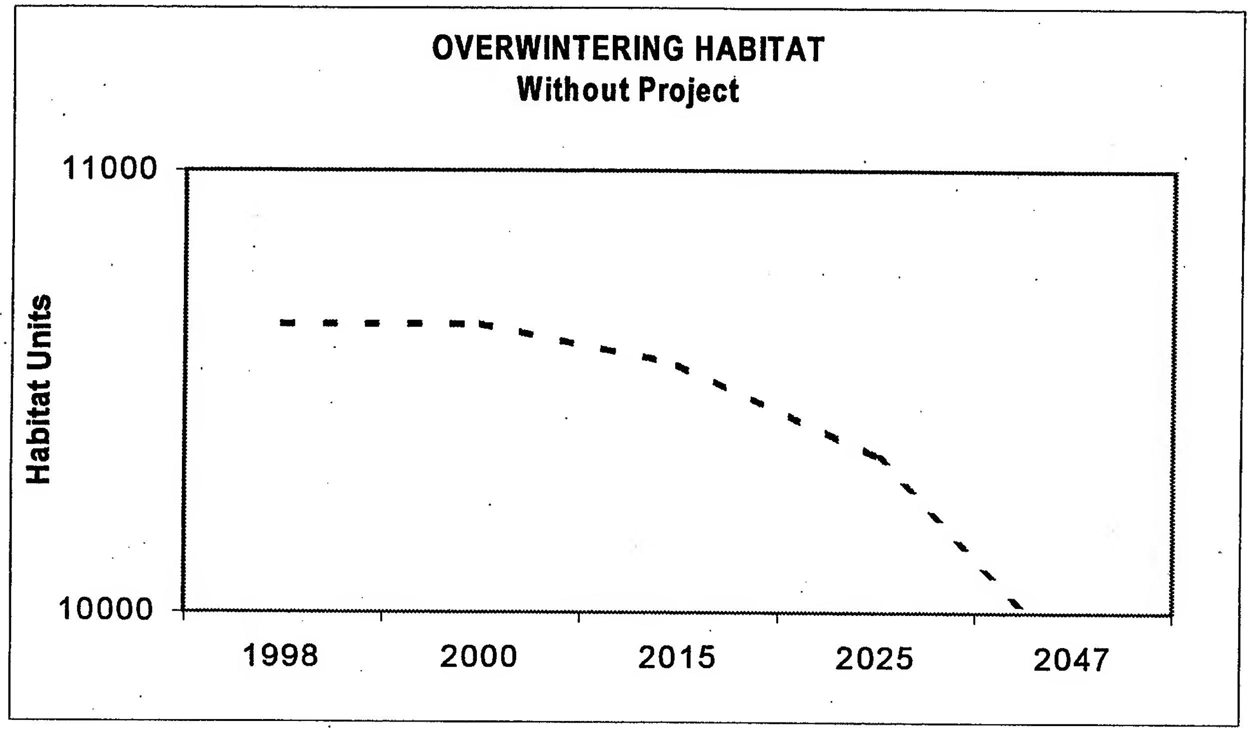
Resurveys of established sediment ranges within the Federal levee reach indicated a net loss of about 3 million cubic yards of material from the entire reach between 1954 and 1988. Most of the erosion occurred prior to 1967 during and immediately following levee construction. Since then, the degradation has tapered off as the channel has adjusted to the new regime. Recent sediment range resurveys covered a very limited length of the reach and are thus somewhat inconclusive. The available surveys downstream of the Federal levee system in Areas 1 and 4 are also somewhat inconclusive although there is some evidence of channel thalweg aggradation at some locations. In the future without-project condition it is expected that the channel (average section and thalweg) will continue to degrade overall at a progressively lesser rate in Areas 9 and 10 with possible continued aggradation in Areas 1 and 4.

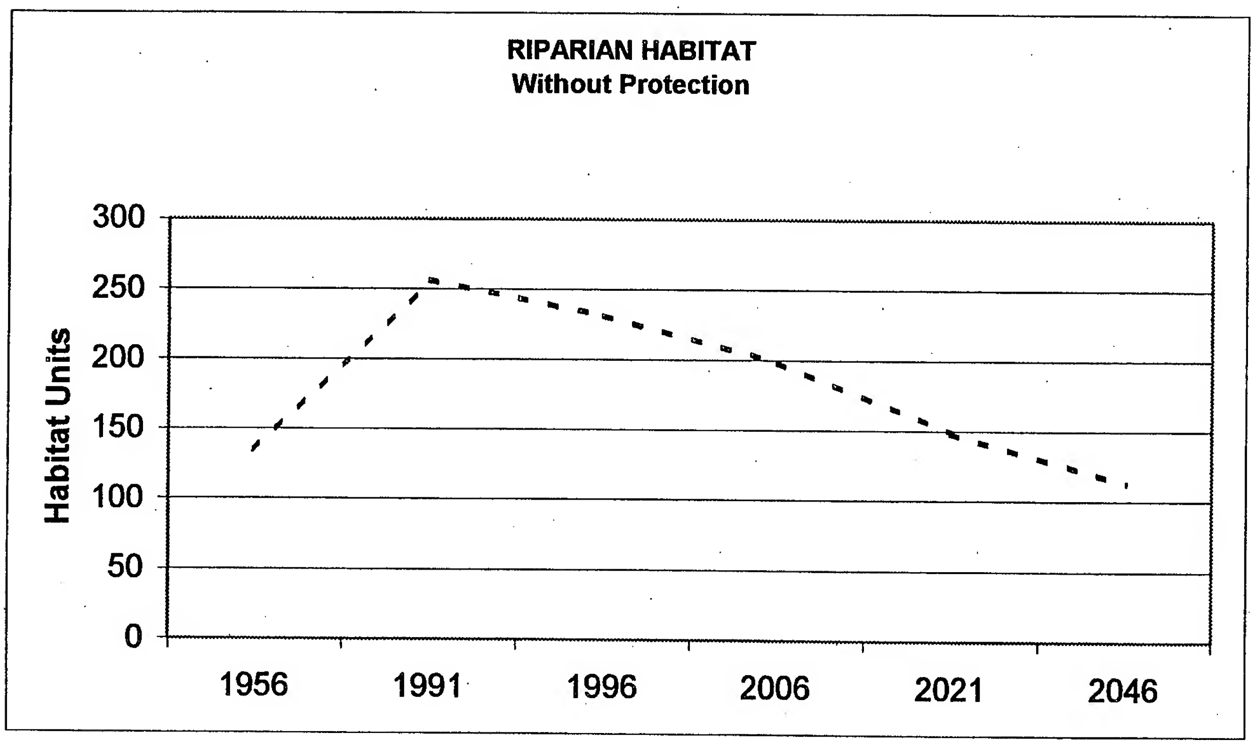
While the net erosion within the study reach may not be significant, localized changes in the channel bed will continue to dominate the river between the levees. In the future without-project condition, the Snake River will continue to form and plug new low-flow channels and braided systems between the levees. Previously observed patterns, including alternating and fluctuating zones of aggradation and degradation, are expected to continue. The problem of flow impingement on the existing levees and the associated cost of placing additional low-flow armor to protect them will also continue. This work is currently performed by the Corps, which is responsible for maintenance of the Federal levees.

The remaining in-channel islands will continue to be eroded, and the existing habitat will be lost. Any new islands that form between the levees will not be in place long enough to establish permanent aquatic and terrestrial habitat. The latter problem is compounded by the exceptionally coarse bed material, which makes plant establishment difficult.

3.2.1 Future Habitat Trends

Habitat analyses conducted as part of the feasibility study showed a future continued trend of riparian habitat destruction within the levees further promoting the shift from a highly diverse and productive ecological system to one where nearly all out-of-channel habitat is primarily gravel from levee to levee. The degradation in riparian habitats has pronounced impacts on both aquatic and terrestrial species. Aquatic habitat analyses conducted in this *Feasibility Study* showed that without intervention there would be a trend of continued significant habitat degradation, including the reduction of vital rearing and overwintering habitats. The following two figures display the trend of continued aquatic and riparian habitat degradation that was identified by the study's environmental modeling.


OVERWINTERING HABITAT
Without Project
Habitat Units
11000
10000
1998
2000
2015
2025
2047


RIPARIAN HABITAT
Without Protection
Habitat Units
300
250
200
150
100
50
0
1956
1991
1996
2006
2021
2046

4. PLAN FORMULATION

4.1 Problem Identification

In the 1950's, the Snake River near Jackson, Wyoming was a highly braided system with a broad floodplain and numerous vegetated islands (Plate 11). Over time, development of the Snake River levee system has created significant changes in physical processes that have resulted in the loss of valued environmental resources. The levees have reduced the cross section of the main channel and have effectively separated it from the floodplain (Plate 12). The resulting concentration of flows lead to a deeper, straighter channel (Plate 13) with higher velocity flows that have removed progressively larger sediment sizes. The overall cross section and thalweg have lowered and the remaining bed material, which is now mostly gravel and cobbles, is constantly reworked by low and high flows.

This constant shifting of the riverbed between the levees has eliminated the natural braiding of the river and has resulted in a number of negative effects. Foremost, it prevents reestablishment of stable islands with mature vegetative stands and associated riparian and aquatic habitat (see Plates 14 and 15). Second, low flows, especially during the recession of the hydrograph, have a tendency to run across the channel and impinge directly onto existing levees. The combinations of impingement, and locally aggrading areas within the riverbed (which locally raise the water-surface elevation) have necessitated construction of additional armor on the river side of the levees. Since the points of impingement can vary from flood to flood, the additional levee protection represents a high maintenance cost that will continue into the future. Finally, flows will continue to attack the few remaining islands as well as unprotected banks. The environmental consequences include a loss of diversity in aquatic, wetland, riparian, and terrestrial habitat as well as reduced value of remaining in-stream, riparian and terrestrial habitats.

4.2 Problems and Opportunities

Section 4.1 provided a general description of water-related environmental resource problems in the study area. The general source of these problems is *increased instability of the river channel*

as a result of flood control improvements that narrowed the historic floodplain. Specific problems that stem from this channel instability include: (1) system inability to establish and maintain sustainable, diverse riverine ecosystem habitats; (2) declining in-stream aquatic habitat (quantity and quality); (3) declining wetland and riparian habitats (quantity and quality); (4) declining habitats (quantity and quality) for sensitive species, including threatened and endangered species. Table 4.1 summarizes the problems focused on in the study.

Table 4.1 – Study Area Problems

General Problem	Specific Problems
Channel Instability	(1) Declining habitat diversity and sustainability
	(2) Declining quantity and quality of in-stream aquatic habitat
	(3) Declining quantity and quality of wetland and riparian habitat
	(4) Declining habitats for sensitive, threatened, and endangered species

To solve problems in the study area, they need to be viewed as opportunities. Table 4.2 presents opportunities to address problems and thereby achieve the study goals and objectives.

Table 4.2 - Study Area Opportunities (Planning Objectives)
(1) Restore habitat diversity and sustainability
(2) Increase the quantity and quality of in-stream aquatic habitat
(3) Increase the quantity and quality of wetland and riparian habitat
(4) Restore habitats for sensitive, threatened, and endangered species

4.3 Significance of Environmental Resources and Degradation

The significance of the project area and it's environmental resources is a function of it's geologic location. The alluvial outwash plain provides riparian and aquatic habitat critical for the life cycle requirements of species within the surrounding Yellowstone ecosystem. The following paragraphs describe the significance of environmental resources within the study area.

The greater upper Snake River begins in Yellowstone National Park and flows in a southerly direction into the Franklin D. Roosevelt National Park before entering Jackson Lake. Jackson

Lake controls about one-third of the flow that enters the project area. From Jackson Lake, the Snake River enters Grand Teton National Park before entering the project area below Moose, Wyoming. Within the project area, from Moose to the South Park National Elk Feedgrounds, the river flows through mostly private riparian properties. Below the Elk Feedgrounds, the river enters a steeper canyon area that is managed by the USFS. The river then enters Palisades Reservoir at the Wyoming-Idaho boundary. The project area constitutes most of the privately owned lands surrounding the Snake River in the region. Throughout most of the ecosystem, the river and its surrounding areas are publicly owned and managed.

The uppermost section of the Snake River within Yellowstone and Rockefeller National Parks is within a pristine natural ecosystem with little to no man-induced degradation. From Jackson Lake downstream the river remains within a pristine ecosystem with the exception of its flow-regime, which is altered by the operation of Jackson Lake. Within Grand Teton National Park, the Snake River follows a natural meandering, semi-braided pattern to Moose, Wyoming. Below the town of Moose, within the study area, the flood plain widens, the slope of the valley increases, and the river forms a braided system. Below the South Park National Elk Feedgrounds boundary, the geology changes, and the river enters a more confined canyon. The terrestrial ecology of the river above and below the project area is a naturally functioning ecosystem managed by the U.S. Department of Interior and the USFS.

4.3.1 Significance and Degradation of Riparian Habitats

This wider braided section of the Snake River had historically provided some of the most valued riparian habitats within its ecosystem. The riparian habitats were characterized by the braided character of the channels forming a diversity of islands and wetlands and supporting various life forms of vegetation. The natural cycle of flooding and channel shifts resulted in habitats ranging from submerged aquatic riverine, to emergent scrub-shrub, willow-alder habitats to sapling and mature deciduous cottonwood stands. The area provided habitat for five endangered species and a wide diversity of fauna from river otters and waterfowl to bald eagles. One the area's most important national values was its wintering habitat. During the severe Jackson Hole winters, when temperatures reach minus 20 °F and minus 30 °F and when snow can accumulate to several feet, big game such as elk, mule deer, and especially moose moved into the valley for cover and food. The proposed project area also provides critical wildlife corridors for the movement of mammals between summer and winter ranges.

Due to the need for erosion and evulsion protection within the project area, the Corps constructed the flood control levee system. When the levees were constructed in the early 1950's through the 1970's, two distinct impacts occurred. The levees provided flood protection which encouraged the construction of homes, which displaced wildlife habitat. The second significant impact was the concentration of flows and the loss of riparian habitats between the levees. The islands of mature cottonwoods and diverse wetland communities have been replaced by single or double river channels with enlarged barren cobble islands. The wildlife cover, food, and corridor values have been significantly reduced.

4.3.2 Significance and Degradation of Aquatic Habitats

The fisheries value of the Snake River remains in a natural state above the study area within Yellowstone and Rockefeller National Parks. The upstream sections above Jackson Lake within Yellowstone and Grand Teton National Parks are pristine, but the overall productive value is low. Since this area is geologically young, the waters that flow over the bedrock and poorly formed soils contain limited nutrient loads. Below Jackson Lake in Grand Teton National Park, the natural integrity of the system remains intact but is influenced by irrigation flows from Jackson Lake. Below Moose, Wyoming, in the study area, the character of the river channel and its aquatic resources have changed dramatically.

The study area has historically been characterized by richer, older flood plains that contributed increased productivity to the aquatic system. The once braided, multi-channel system with its diverse adjacent habitats has been replaced with a single or double channel and cobbled shoreline. The value of the shoreline and the diversity of the braided river channel has changed significantly. As the leveed reach has become increasingly less diverse, overwintering habitat has become a significant limiting factor for some species. Survival through the harsh low-flow winter months is a critical life cycle requirement. Harsh winter temperatures and low flows limit cutthroat trout survival. During the winter months trout can survive only in pools that provide protection from ice and predators. Winter predators such as bald eagles, river otters, and fish-eating waterfowl can easily prey on the trout within their restricted areas of habitation. Recent studies have shown that mature cutthroat trout move from below Jackson Lake to the project reach to survive the winter. Not only do the mature fish move downstream, but there is also some evidence that fish from the canyon area may move upstream to survive the winter.

4.3.3 Institutional, Public and Technical Significance of Area Resources

The significance of natural resources in the study area is clear. Technical studies have identified the importance of diverse and productive riparian and aquatic habitats for the survival of fish and wildlife through the ecosystem's harsh winters. Institutional significance of the study area is demonstrated by its endangered and threatened species. Public significance is demonstrated by the strong local support for the proposed project as evidenced by the sponsor's construction of a demonstration project in the study area. The study's evaluation of significance is further described in the following section.

4.4 Scoping of Study Area

The area covered by the reconnaissance study included the Snake River and tributaries, and the associated 500-year floodplains in the vicinity of Jackson Hole, Wyoming. The reconnaissance study reach was bounded by Moose, Wyoming, near the southern boundary of Grand Teton National Park, and the U.S. Highway 26 Bridge crossing approximately 7 miles south of Jackson, and had a floodplain area of roughly 25,000 acres. The array of Federal levees constructed in the 1950's and 1960's generally reduced the floodplain area to 2,500 acres, or only 10 percent of the original extent. An initial Project Study Plan for the feasibility study again involved the entire 500-year floodplain from Moose to South Park Feed Ground. In order to control study costs and make data collection and analysis feasible, the study team reviewed aerial photography and data generated during the reconnaissance study to select 12 sites that provide the best opportunity for restoration from a fluvial geomorphology and wildlife habitat standpoint.

A new Project Study Plan was then developed for the 12 specific sites. The twelve sites are shown in Plate 3. The cost of the study was reduced from over $3 million to just under $2 million, a significant reduction, but still out of the range of the sponsor's fiscal ability. It became apparent that further efforts to reduce cost could not be effective without further reductions in the overall scope of the study. In an effort to reduce the scope, it was decided to determine and describe the overall environmental significance of each site. The overall study area has high national environmental significance as described in the *Jackson Hole, Wyoming, Flood Damage Reduction, Fish and Wildlife Habitat Restoration, Reconnaissance Report* (June 1993). To formulate a reduced scope, each of the 12 sites was evaluated in regard to its individual

significance resulting the identification of 4 sites for detailed evaluation. The screening process is described below.

4.4.1 Significance-Based Preliminary Screening Framework

In 1983, the U.S. Water Resources Council published the *Economic and Environmental Principals and Guidelines for Water and Related Land Resources Implementation Studies* (P&G). The methodology in P&G is the analytical procedure currently used by the Corps in evaluating alternative water resources projects. To be considered in plan formulation and evaluation, P&G requires that environmental resources be "significant." Significant environmental resources are defined as those that are institutionally, publicly, or technically recognized as important. As defined in P&G, the term of significant means "likely to have a material bearing on the decision-making process." In terms of environmental plan formulation and evaluation, the significance of environmental resources based on their nonmonetary values may be established by institutional, public, or technical recognition of the importance of the environmental resources or attributes in the study area.

a. Institutional Recognition. The study areas are institutionally recognized by several national laws and regulations. Part of the original area in the reconnaissance study was within Grand Teton National Park with the remainder immediately downstream and adjacent. The southern most section of the study area is adjacent to South Park National Elk Feedgrounds (a state preserve for wintering elk). Within the project area are six bald eagle nesting territories and habitat for five other nationally recognized endangered species. Over 50 percent of the project is classified as wetlands. The scarcity of structural and biological resources which directly support institutional resources was addressed in this study.

b. Public Recognition. As indicated in the project support section of this document, the study area receives significant interest from local and regional environmental groups. The study area is also used by sportsman and recreationists from across the United States. The area, located between a national park and national forest, has considerable recreational value. The fine-spotted-cutthroat trout is an endemic wild fishery that provides an $11 million fishery to the county. The study has the potential to improve its value .

c. Technical Recognition. Spring creeks are relatively small streams fed by groundwater discharges of clean, clear water of relatively uniform annual temperature. They provide the critical spawning habitat for fine-spotted-cutthroat trout, which in turn provide a forage base for bald eagles. All eagle nesting habitats in the project area are associated with spring creeks.

All 12 sites were ranked individually based on their institutional, public, and technical recognition. Significance rankings are listed in Table 4.3.

Table 4.3 – Site Significance Rankings

SITE RESTORATION - COMPARING 12 ALTERNATIVE STUDY AREAS

CRITERIA RATING INDICES:

BEST	1
AVERAGE	2
WORST	3

RAW SCORES:	NATIONAL SIGNIFICANCE CRITERIA			
	Institutional Recognition	Public Recognition	Technical Recognition	Totals
	(1)	(2)	(3)	
MEASURE:				
ALTERNATIVE 1	1	1	1	3
ALTERNATIVE 2	1	1	1	3
ALTERNATIVE 3	1	1	1	3
ALTERNATIVE 4	1	1	2	4
ALTERNATIVE 5	2	2	3	7
ALTERNATIVE 6	2	2	3	7
ALTERNATIVE 7	2	2	2	6
ALTERNATIVE 8	3	3	3	9
ALTERNATIVE 9	1	1	3	5
ALTERNATIVE 10	1	1	1	3
ALTERNATIVE 11	1	2	2	5
ALTERNATIVE 12	1	2	2	5

4.4.2 Multi-Objective Analysis for Site Selection.

To further refine the scoping effort, a multi-objective approach was developed. Objectives developed with public input during the reconnaissance phase and refined at the Reconnaissance Review Conference were used in a matrix analysis. The study objectives were defined as:

wetland restoration--riverine and palustrine; riparian restoration--island protection and restoration; and endangered species habitat protection and creation.

A multi-objective analysis was conducted using the following objectives:

- Channel Creation. Channel creation to restore fisheries--wetland values dependent on surplus gravel and disposal options (*i.e.*, users of gravel).
- Island Protection. Island protection measures to preserve riparian island values.
- Island Restoration. Island restoration measures to restore lost riparian values.
- Fish Habitat Creation. Fish habitat creation (low energy areas in high energy environments) through stream structure alteration (*i.e.*, spur dikes).
- Headgate Opportunities. Headgate opportunities to provide for future water diversions to restore spring creeks and wetland-riparian habitats.

The ratings for each of these objectives for each project area are listed in Table 4.4.

Table 4.4 – Restoration Features Comparison

SITE RESTORATION – COMPARING 12 ALTERNATIVE STUDY AREAS

CRITERIA RATING INDICES:

BEST	1
AVERAGE	2
WORST	3

RAW SCORES:	**MULTI-OBJECTIVE ENVIRONMENTAL CRITERIA**					
	Channel Creation	**Island Protection**	**Island Restoration**	**Fish Habitat Creation**	**Headgate Opportunities**	**Totals**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	
MEASURE:						
ALTERNATIVE 1	1	1	1	1	3	7
ALTERNATIVE 2	1	1	1	1	2	6
ALTERNATIVE 3	1	1	1	1	1	5
ALTERNATIVE 4	1	1	1	1	3	7
ALTERNATIVE 5	2	2	2	2	1	9
ALTERNATIVE 6	3	2	2	2	3	12
ALTERNATIVE 7	3	1	1	1	2	8
ALTERNATIVE 8	3	3	3	3	3	15
ALTERNATIVE 9	1	2	2	2	1	8
ALTERNATIVE 10	2	1	1	1	1	6
ALTERNATIVE 11	3	2	1	1	2	9
ALTERNATIVE 12	3	2	2	2	3	12

The values relating to overall national significance and environmental engineering feasibility were integrated, and the multi-objective analysis was given a 1.5 weight to select the four sites that provide the best overall opportunity for success. The multi-objective approach was given additional weight because the sites providing the most opportunity provided a synergistic effect and the greatest overall opportunity. Six sites provided similar opportunity. Three sites on the downstream reach had very similar ratings and opportunities for restoration. The study team decided to allow the scoping process with local input and specific knowledge of property ownership and cultural concerns to select the best site of the three downstream sites of equal value. The four sites selected are one of either Area 1, 2, or 3 (Area 1 was selected) and Areas 4, 9, and 10.

Table 4.5 – Site Comparisons

SITE RESTORATION - COMPARING 12 ALTERNATIVE STUDY AREAS

CRITERIA RATING INDICES:

BEST	1
AVERAGE	2
WORST	3

RANKED INDEXED SCORES:

APPLY 28.5% IMPORTANCE FACTOR TO 3 PUBLIC AWARENESS CRITERIA

APPLY 71.5% IMPORTANCE FACTOR TO 5 MULTI-OBJECTIVE ENVIRONMENTAL CRITERIA

		Index Application Rate Per Criteria	Number of Criteria	Total Index Points	Index Application Rate per Criteria	Number of Criteria	Total Index Points	Grand Total Index Points		
RATING:										
BEST	1	0.095	3	0.285	0.143	5	0.715	1		
AVERAGE	2	0.19	3	0.57	0.286	5	1.43	2		
WORST	3	0.285	3	0.855	0.429	5	2.145	3		

	NATIONAL SIGNIFICANCE CRITERIA			MULTI-OBJECTIVE ENVIRONMENTAL CRITERIA					
	Institutional Recognition	Public Recognition	Technical Recognition	Channel Creation	Island Protection	Island Restoration	Fish Habitat Creation	Headgate Oppor-tunities	Totals
MEASURE	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Alternative 3	0.095	0.095	0.095	0.143	0.143	0.143	0.143	0.143	1
Alternative 2	0.095	0.095	0.095	0.143	0.143	0.143	0.143	0.286	1.143
Alternative 10	0.095	0.095	0.095	0.286	0.143	0.143	0.143	0.143	1.143
Alternative 1	0.095	0.095	0.095	0.143	0.143	0.143	0.143	0.429	1.286
Alternative 4	0.095	0.095	0.19	0.143	0.143	0.143	0.143	0.429	1.381
Alternative 9	0.095	0.095	0.285	0.143	0.286	0.286	0.286	0.143	1.619
Alternative 7	0.190	0.190	0.190	0.429	0.143	0.143	0.143	0.286	1.714
Alternative 11	0.095	0.190	0.190	0.429	0.286	0.143	0.143	0.286	1.762
Alternative 5	0.190	0.190	0.285	0.286	0.286	0.286	0.286	0.143	1.952
Alternative 12	0.095	0.190	0.190	0.429	0.286	0.286	0.286	0.429	2.191
Alternative 6	0.190	0.190	0.285	0.429	0.286	0.286	0.286	0.429	2.381
Alternative 8	0.285	0.285	0.285	0.429	0.429	0.429	0.429	0.429	3

4.4.3 Preliminary Screening Results

Thus, the *Feasibility Study* focuses on four proposed restoration alternative sites referred to as Areas 1, 4, 9, and 10. The four sites are shown on Plate 4. The sites are all located within the Snake River in a reach extending from a point 3 miles above the Highway 26 Bridge on the downstream end, to the Gros Ventre River confluence on the upstream end. In the vicinity of the

project reach, the right (west) bank Federal levee is continuous from RM 947.6 (near Area 4) to beyond the Gros Ventre River confluence. The (east) bank Federal levee extends from RM 947.6 (near Area 4) to a point roughly 1.7 miles upstream of the Jackson-Wilson Bridge on Highway 22. The remaining 2.5 miles of bank (4.4 river miles) are currently unleveed.

4.5 Formulation of Alternatives

At each of the four study areas, different restoration features were combined into alternative restoration plans for each site. This section describes the restoration measures that were considered and provides a summary of the different configurations of measures at each of the study areas.

4.5.1 Restoration Measures

Restoration measures consist primarily of: construction of eco-fences; excess gravel removal; placement of logs and root wads designed to protect and reestablish wetland and riparian habitats and; creation of side channel backwater areas and off-channel pools. (See Plates 29 through 33.) The eco-fences will be placed at the front and sides of existing wooded islands to protect an existing resource or in areas where riparian vegetation has been lost in an attempt to regain the lost soil and vegetation. Generally, attempts to regain vegetation area had been limited to that which existed prior to 1973 in order to avoid reducing the level of flood protection that existed at that time. The purpose of the fence structures is to block, slow down, or deflect the force of the current during high-flow periods in order to protect existing vegetation and allow new vegetation to become established. Fences have been used effectively in low velocity regimes in a number of other instances. Their long-term effectiveness in the high-velocity regime that exists in the area covered by this study remains to be demonstrated.

Gravel and cobbles will probably accumulate to some extent with any reduction in the flow velocity, but flows must be reduced well below 2 fps if a layer of soil is to be reestablished. Willows, and other vegetation which grow in the gravel bed will assist in reducing velocities and encouraging the deposition of silt if they can be protected from direct attack long enough to become established. As vegetation becomes established it further slows flow velocities and encourages accelerated sedimentation.

If a fence fails to perform satisfactorily, it is possible to add more cross cables or wire mesh to increase the trapping efficiency of the structure. A few seasons of operation may be required to measure the effectiveness of the fences and to adjust the existing fence designs for optimum performance. If the fences operate successfully, debris will be swept by the eddy current into the space between each fence, and a raft of logs, limbs, and other flotsam will collect upstream of the fences and form the matrix through which willows and other vegetation will become established. Sand and gravel will collect in the triangular, protected zone downstream of each fence. As vegetation becomes established it will further resist the flow and encourage the accumulation of a new layer of silt, which will support progressively larger varieties of vegetation.

In most cases, the fences will have very little effect on overall river conveyance since they are generally located where conveyance is reduced (*i.e.*, near the banks of existing islands), or where the river has ample room to cut a channel around the protected area. At other locations the fences protect and maintain existing stands of timber, which presently block most of the flow through the affected area. Proposed fences, which encroach on open areas, will nearly always be located where heavy stands of mature vegetation and soil once existed (but were removed by flood flows) and at the site of previously blocked most flood flows.

Gravel removal is designed to accomplish several objectives. In some areas gravel will need to be removed initially in order to increase the capacity of the stream and offset the loss of conveyance resulting from the eco-fences. The stream would naturally enlarge the channel and regain its conveyance with time, but a flood coming in the season following the completion of the fence might raise the water a small, but unacceptable amount above the regulatory flood level. Oversize gravel (the +4 inch material, which generally constitutes from 5 to 20 percent of the mixed gravels in the bed) will be retained and returned to the channel bed and the upstream ends of adjacent islands. This large material is more resistant to movement and actually forms a protective armor layer when flow velocities are below the critical shear stress for the available sizes.

A second function of gravel removal is to reduce the supply of gravel to an area that is overloaded. This, if combined with measures that increase gravel bar stabilization, will result in channel entrenchment and a reduction in the rate and frequency of lateral movement. A third function is to take the pressure off of an eroding bank by opening up existing secondary channels and shifting some of the flow back toward the center of the meander belt. Eco-fences and anchored debris are designed to encourage vegetation growth and help to stabilize the channel

pattern. The level of success in maintaining an alignment will probably vary widely with the location and degree of bank stabilization accompanying the gravel removal.

The above objectives could be achieved with reasonable confidence in a meandering channel with a low sediment load. However, the Snake River carries a heavy bedload and is very unstable and braided. It is very difficult to determine how much sediment is being transported, where sediment will be deposited next, or where the channel will be after the next flood. By its very nature, the river is unpredictable and may not respond as desired in some areas.

Changes in sediment transport and river hydraulics, resulting from the implementation of various restoration measures, will have environmental impacts, which will need to be considered. In the remainder of the report the term "improved channel" is sometimes used interchangeably with the term "restored channel" to refer to the modified condition after restoration measures have been implemented in an area.

The grain sizes of materials on the surface in the study areas vary considerably from silt to cobbles 5 to 10 inches in mean diameter. The size depends to a great degree on the velocity of flow at the particular location. However, a foot or more below the surface the material is more uniformly distributed with very little silt and generally less than 15 percent larger than 4 inches. When the river is returned to flow over an excavated area there will be an initial increase in turbidity as the flow picks up the fine material from the surface. This should be of very short duration, perhaps a few hours. Later on, as the flow increases during winter floods or the spring runoff period, the bed will be reworked, and one of several processes will dominate. Fine material in the bed will be entrained and put into suspension. Then, depending on the sediment supply from upstream, more sediment will be deposited than is entrained; an equilibrium will be established between entrainment and deposition; or, if there is a deficient supply, erosion of the bed will occur until enough the large material remains to form a new continuous layer over the bed which will protect the underlaying material from further erosion.
Cobbles which form the new armor layer would come from material transported into the site from upstream, oversize material physically returned to the bed during gravel-removal operations, and material existing in the bed. In the extreme case, with a deficiency of supply from upstream, and no return of cobbles to the bed, the channel bed could degrade to a depth of 2 to 10 feet depending on the amount of large sized material in the bed. Restoring the +4 inch material will significantly reduce the depth of degradation from an average runoff event, since this material will be redistributed over the surface by the current to form a new armor layer.

In some areas root wads or logs will be anchored. The root wads are designed to accomplish some of the same objectives as the eco-fences. They will have less of a visual impact and should spread the effect over a larger area. In areas of low velocity sand and silt will collect downstream of the debris and encourage the establishment of vegetation. In higher velocity areas, a sufficient number of root wads will tend to slow the velocity and deflect most of the current around the area to be protected. In some areas, when exposed to the main current the root wads will actually increase erosion by flailing around on the restraints and stirring up the gravel. In these areas, holes, several feet in depth, will be eroded in the channel where each root wad is anchored.

4.5.2 Design Criteria for Restoration Measures

For purposes of comparing the costs and benefits of different levels of protection, it was necessary to select criteria for design and assign a probability of success to various elements of the design. Since there was virtually no historic data of a type that could be used for a rigorous probability analysis for this type of project, probabilities were primarily based on experience and judgment.

The maximum design life of 50 years seemed to be a reasonable value, since woody vegetation will reach a mature level during that time. It also corresponded roughly to the period of aerial photographic data documenting changes in the channel and surrounding vegetation. During the past 50 years, virtually all of the vegetated islands within the meander belt were destroyed at one time or another by the changing channel patterns. In order to provide a comparison, shorter design periods that actually represent intermediate levels of reliability in the selection of structural elements and restoration measures were selected.

From the frequency curves shown in Appendix B, Hydrology, it can be seen the peak annual discharges for average return intervals of 15, 25, and 50 years are 22,500, 24,000, and 26,500 cfs. Obviously there is not enough difference in these flows to serve as a criteria for design of structures whose probability of failure is related more to attack by impinging flows, impact by floating debris, and changes in channel alignment, than by a specific flood frequency. For this reason it was decided that a design based on attack by floating debris under three different impinging flow velocities along with the traditional static hydraulic loading, would be a

more reasonable approach. Impinging flow, for purposes of this analysis was defined as flow that had a much greater attack velocity due to a local steepening of the upstream channel.

The design impingement velocities were based on expected levels of attack. Velocities of 4 fps or greater could be expected when the structures were exposed to high flows even without impingement conditions. For this reason structures should not be designed for anything less than 4 fps. Impinging velocities of 8 fps were frequently seen in the data, and 12 fps occasionally appeared in the data. These velocities were used as a basis for the development of four separate fence designs.

Structures designed for 4 fps would suffer substantial damage if exposed to direct attack by an typical impinging flow. The probability of being exposed to this type of flow may range from 5 to 10 percent each year based on a rough estimate of the length of levee exposed to impinging flows. If 7 percent of the structures were substantially damaged each year, this would roughly correspond to a 15-year life for structures designed for 4 fps. Structures designed for 8 fps would be more likely to survive some impinging attack, perhaps providing a 25-year average life. However, with the present design, the structures would not provide enough continuity to restrict the channel to a fixed alignment.

The braided channels will eventually bypass even the strongest structures, attack the vegetated islands from an unprotected angle and eventually render many of the structures useless. It does not seem reasonable, based on the past erosional history of the river, to assign a project life greater than 50 years. Vegetative growth was based on the assumption that over the entire project the average, effective life of the fences would correspond to the selected intervals. On an average, substantial reconstruction of the entire project would be required at the indicated intervals.

In some areas the restoration measures may be very successful, in others there is likely to be extensive failures. By analyzing past erosion trends and channel patterns, an attempt has been made to maximize the probability that most of the measures will be located in areas where they will meet with an acceptable level of success.

4.6 Description of Restoration Alternatives at the Four Project Areas

This section provides a description of the management measures that make up each of 4 alternatives at each of the 4 study sites for a total of 16 alternatives. Area 1 is described first, followed by Areas 4, 9, and 10.

4.6.1 Proposed Restoration Measures for Area 1

This section provides a site description for Area 1 and identifies specific proposed restoration measures.

4.6.1.1 Area 1 Description

Area 1 encompasses a long sweeping bend in the Snake River and its associated overflow channels and wooded riparian zone (see Plates 4 and 16). It is located about 3 miles upstream of the Highway 26 Bridge, starting at the confluence of Spring Creek and extending upstream about 2 miles. The Snake River enters the area flowing generally south, then swings nearly 90 degrees to the east as it comes up against the Snake River Range which blocks its southward path along the lower one-third of this area. The river and its adjacent wooded riparian zone spreads out to a width of about one mile around the bend, but narrows to 2,000 feet or less where the braided channels converge at the lower end. At present the river generally flows around the outer edge of the riparian zone. During high-flow periods, the river overflows into a network of smaller channels that cut across the bend and empty back into the Snake River along the lower half of the bend. During low-flow periods the upper ends of these channels may be dry, but progressing downstream, water seeping in from the shallow aquifer keeps the larger branches flowing during the entire summer.

The channel is highly braided, with 2- to 5-degree braiding over most of its length. The adjacent floodplain is wide and flat. During high-flow periods the channel boundaries are poorly defined and constantly changing. Gravel may completely fill the channel at some locations causing the flow to fan out over a wide area.

A review of historic aerial photographs indicates that the active channel has frequently changed course and pattern. A USGS quad sheet, based on surveys taken 1927-31, indicated that the

channel at that time was more centrally located within the meander belt and divided into three main branches. Both of the east branches emptied into Spring Creek, which joins the Snake River at the downstream end of the bend. By 1945 it appeared that the central branch of the channel was being abandoned, but a large channel still cut across to Spring Creek. Over the years the channel moved westward, progressively eroding a 1,000-foot wide wooded riparian zone and cutting into developed pasture lands to the west. In the process the river almost completely abandoned the branch into Spring Creek. Sheet flow still covers the interior gravel bars during spring floods, but willows are springing up, and sand and silt is building up on large expanses which were formerly bare cobbles.

The date for the most recent westward channel movement is not known. There was some westward erosion evident in 1956. A couple of loops were cut into the zone between 1960 and 1962. Large areas of vegetation were washed away between 1967 and 1971, between 1974 and 1981, in 1986, and between 1992 and 1996.

Near the downstream end of Area 1 a large portion of the Snake River formerly flowed into and along the present course of Spring Creek and then flowed back into the main channel from the left. The momentum of the lateral flow and sediment replenishment from this branch of the Snake River probably tended to keep the channel pushed up against the hills to the south. A groin, located just above the confluence on the left side, can be seen in 1953 aerial photos, but appears to be partially or completely destroyed in 1956 photos. Since 1962 the river has progressively cut away slices of the left bank. By 1996 the river had cut nearly 800 feet into riparian land near the mouth of Spring Creek.

Several factors suggest that the river is either moving large volumes of gravel with no net loss; or the area is aggrading:

- The riverbanks are poorly defined or nonexistent.
- The river is invading new areas beyond the meander belt.
- The meander belt is 3 to 4 times as wide as the active channel.
- During peak flow conditions, flow is often shallow and spread out over mid-channel islands which appear to include most of the channel cross section.
- There is an absence of recent terrace formation or other evidence of channel entrenchment.

The low-flow channel exhibited a wide variation of patterns over the years. During some years, such as in 1996, a definite, repeated pattern of fairly uniform meander loops could be seen within the overall braided pattern. In 1945 there was little, if any, regular meandering pattern identifiable within the overall braiding. The 1996 pattern appeared to be more typical of identifiable patterns during the 1945-97 period.

4.6.1.2 Area 1 Restoration Measures

a. Channel Alignment. The natural channel pattern will be retained and allowed to develop to the extent possible. However, several existing channels will be enlarged, as indicated on Plate 16, to shift some of the flow back toward the center of the meander belt, take some of the erosive pressure off of the right bank, and allow reestablishment of a riparian zone in this area.

b. Removal of Excess Gravel. A gravel-removal zone, designed to match a typical second-degree braiding pattern, was selected at the upstream end of Area 1. Removal of excess gravel at this location will reduce the supply downstream, encouraging moderate entrenchment of the downstream channels and reducing the frequency and extent of lateral movement. Cobbles over 4 inches in mean diameter will be retained to form an armor layer on the bed and banks of the channel.

The Area 1 gravel removal site was chosen for the following reasons:

- The location allows easy access along the west side from the Taylor Creek Levees or the nearby county road.
- The location will reduce the supply of gravel entering the site while minimizing the area that will be disturbed while excavation is in progress.

During hydraulic modeling of the channel modifications described above, it was found that the eco-fences resulted in a calculated rise in the water level upstream. To offset the effect of the fences, additional excavation is proposed along several existing, secondary channel alignments. This excavation should take some pressure off of the right bank by shifting a majority of the flow back toward the center of the meander belt. The channel modifications will shorten the effective length of the channel and increase the channel conveyance. The sediment supply will be reduced by the upstream sediment trap. If successful, these modifications should maintain adequate

conveyance through this reach in the future with little or no maintenance. After completion of the project, the area should be monitored by periodic resurveys of sediment ranges to assure that the amount of sediment removed from the sediment trap does not result in excessive channel entrenchment downstream.

c. Pool and Channel Restoration. Two existing channels were identified and selected for restoration measures. Four pool sites were selected along these channels. The selected sites provide varying degrees of exposure to erosion and sediment inflow. The two pools farthest from the main channel will collect finer sediment and should survive the longest. Connecting channels and associated pools will create flow and depth diversity. Root wads and other in-water debris will provide shade and shelter for fish and other aquatic life.

d. Eco-Fences. Eco-fences and root wad fields along the west bank of the channel are designed to collect sediment, and encourage woody vegetation growth. The objective is to stop westward channel movement and recover most of the riparian habitat lost since 1973. The proposed locations for eco-fences cover areas formerly occupied by mature riparian vegetation, which has been destroyed since 1973. Eco-fences on the left side of the channel are designed to protect large stands of mature cottonwoods should the river shift back eastward across the meander belt. As experience is gained, it may be necessary to make some adjustments or modifications to the fences in order to improve their debris-trapping efficiency or to control erosive velocities between the fences. The modifications might consist of the addition of fence spurs connected to the existing fences or the placement of additional fences or fence panels between the existing fences.

4.6.2 Proposed Restoration Measures for Area 4

4.6.2.1 Area 4 Description

Area 4 covers a braided reach of the river starting at the downstream end of the Federal levee project and extending downstream a distance of 1.6 miles. Fish Creek, Mosquito Creek, and Cottonwood Creek enter the Snake River from the right (see Plates 4 and 17). The Upper Imenson Levee forms a boundary to the left. Prior to construction of the Federal levee project the river often followed an alternate course well to the right of the existing levees, with a significant flow following the present course of Fish Creek. During high-flow periods some of

the flow escaped into spring creeks which branched off of the main channel in the riparian zone to the left. Levees and levee extensions now cut off most of the overflow into these channels.

Historic aerial photographs indicate that the river was rather unstable in this area. Flows followed alternate paths through the area, sometimes spreading out over a fairly wide expanse, and at other times cutting a single narrow channel through the reach. A characteristic, low-flow meander pattern did not appear to be present in this location. The active meander belt has experienced considerable lateral expansion between 1954 and the present. Large areas were eroded in 1973, and again in the 1986-97 period. Between 1945 and 1954 the active, vegetation-free zone of the channel occupied an average width of about 1,000 feet. In 1977 floodwaters spread out to a width of 2,400 feet with very little vegetation left in between. The location and method used in previous cross section surveys do not provide a sufficiently accurate basis for analyzing gravel erosion or deposition in this area. However, several factors strongly suggest that gravel is building up again in this area:

- The levees immediately upstream of the study area have severely restricted the opportunity for flood flows to spread out and flow into alternate channels. Gravel transport and deposition is now restricted in the area between the levees.
- Repeated resurveys of monumented sediment ranges in the upstream Federal levee reach indicate a net loss of gravel between the levees.
- Termination of the right-bank levees theoretically provides an opportunity for transported gravels to drop out as the flow spreads out over the unrestricted floodplain.
- The evidence of progressive widening of the meander belt is consistent with the expected response of the meander belt to excessive gravel deposition in this area.

4.6.2.2. Area 4 Restoration Measures

a. Channel Alignment. The channel at this site has been extremely unstable over the last 50 years, with no identifiable, characteristic, low-flow channel pattern. The low-flow channel pattern utilizes an average meander length observed at other sites within the overall study reach, and represents a pattern that the channel may naturally assume after implementation of restoration measures. If the channel has shifted to the far right or left side of the meander belt prior to project implementation, some excavation may be required along the indicated channel alignment in order to shift the low-flow channel back to the center of the meander belt. This

should be a one-time operation. The channel pattern, gravel excavation sites, and other restoration measures for Area 4 are indicated on Plate 17.

b. Removal of Excess Gravel. The supply of gravel entering this site from upstream will be reduced in order to increase channel stability. Two areas were designated for gravel removal. The size of these sites has no bearing on the amount of gravel to be removed. The maximum area of disturbance during any year will be less than one-half of the delineated areas.

The Area 4 gravel removal sites were chosen for the following reasons:

- The locations provide easy access for equipment using levee access roads along both sides of the river.
- The shape and size of these sites match active gravel exchange areas at these locations, as observed in the 1996 aerial photos. The shape of the upper site was modified to allow room for partial recovery of vegetation and soil lost on a nearby wooded island since 1973.
- Location of the gravel sites along the left bank provides a high degree of assurance that gravel will be intercepted before it enters the area of greatest instability. Large cobbles will be retained during gravel removal and will be used to armor the upstream and downstream ends of the pools.

c. Pool and Channel Restoration. In addition to the gravel sites, three smaller sites were selected off of the main channel where they would be fed by spring creeks or secondary channels, and where they would be protected to some degree from direct erosive attack during flood flows. The small channels feeding and draining the two larger pools will provide opportunities for fish habitat improvement.

d. Eco-Fences. Eco-fences will be used to protect several existing islands supporting mature woody vegetation. The fences will be designed to collect debris and to slow and deflect the flow during average spring runoff periods, but they will be over-topped during extreme floods.

e. Spur Dikes. Groups of spur dikes will be located at two points along the levees. These dikes will provide velocity diversity and resting areas for fish. Properly spaced, they could provide a secondary benefit by providing increased erosion protection for a short reach of the levee.

4.6.3 Proposed Restoration Measures for Area 9

4.6.3.1 Area 9 Description

Area 9 covers a 1-mile reach of the Snake River in the vicinity of the Jackson-Wilson Bridge (see Plates 4 and 18). The downstream limit is just below the Jackson-Wilson Bridge. The upstream limit is about 700 feet upstream of the Prosperity Ditch intake. The earliest available map for this area is a 1946 USGS quad sheet, which was a reprint of a 1901 map, based on 1899 topographical surveys. This map indicates that the channel was braided at that time. Within the study reach, the lower two-thirds of the channel was divided into two main channels that extended downstream through the Jackson-Wilson Bridge. Later maps and aerial photos showed a similar pattern. Rock-filled timber-cribs were used to construct bridge approach walls, four large spur dikes on the left bank, and an isolated section of levee at the Prosperity Ditch inlet. These structures were included in 1938 maps of the area. Several of the spur dikes can still be seen along the left bank upstream of the bridge.

The bridge forms a rather severe constriction in the active meander belt. During the early and middle 1950's the active channel widened considerably just upstream of the bridge. This may have been a response to unusually high flows and associated gravel deposition upstream of the bridge. Levee construction immediately upstream of Area 9 probably resulted in additional transport into this reach. The area of exposed gravel increased by 28 percent between 1944 and 1953, leaving only 15 percent of the meander belt in vegetated islands. Construction of the levees through this area in the late 1950's and early 1960's narrowed the active meander belt, funneled flows through the bridge, and probably increased the efficiency of gravel transport through this area. In 1996 there was actually more vegetative cover than in the 1950's and early 1970's. Aerial photographs indicate rather extensive gravel removal below the bridge along the left bank and at the upstream end of the study reach in the 1960's and early 1970's. Part of the removal work was for levee construction.

4.6.3.2 Area 9 Restoration Measures

a. Channel Alignment. The alignment for channels in this area follows a typical alternating pattern that has existed since about 1960. By encouraging the river to follow one or both of the selected channels some vegetation growth should be possible in areas which were frequently

destroyed by the shifting channel. Some excavation will be needed, at least initially, to stabilize the channel until vegetation can become established.

b. Gravel Removal. Some gravel removal will be required to keep the selected channels open, and to provide additional flow area to offset flow resistance caused by new vegetation growth. If restoration measures are effective, only limited gravel reshaping or removal may be needed in the future. Cobble sized material will be returned to the bed and to the upstream ends of islands to retard erosion.

c. Pool and Channel Restoration. Several pool sites were selected in the protected area near the left bank levee. Sites were selected where direct exposure to the main current would be minimized. Small secondary channels connecting these pools should provide opportunities for fish habitat improvement.

d. Eco-Fences. Eco-fences are designed to reduce velocities and collect sediment, allowing the soil to rebuild and vegetation to extend out from the remnants of a wooded island. Cobble armor and anchored root wads will be used to break the force of the current and allow vegetation to become reestablished on islands between the selected channels. Abandoned bridge piers will serve as anchors for some of the fencing.

e. Spur Dikes. Groups of spur dikes will be located at three points along the levees where flow impingement or long reaches of sustained, high-velocity flow is expected. These dikes will provide velocity diversity and resting areas for fish. They will also strengthen and increase the effectiveness of the adjacent levees.

f. Bed Stabilization. A bed of rock is shown connecting the left bank levee with the debris fences. This material is designed to allow passage of flood flows while preventing the establishment of a permanent channel through the protected area along the left bank levee.

4.6.4 Proposed Restoration Measures for Area 10

4.6.4.1 Area 10 Description

Area 10 covers a 2-mile reach of the Snake River at the Gros Ventre River confluence (see Plates 4 and 19). The Snake River runs south, directly into Gros Ventre Butte, then turns west in the lower half of the study reach. The earliest available map for this area is a 1946 USGS quad sheet, which was listed as a reprint of a 1901 map with some roads and other development added. The map topography was surveyed in 1899. This map depicted a braided channel pattern with up to three main branches. The Gros Ventre appeared to enter the Snake River over 1,000 feet upstream of its present confluence. A 1938 map indicated a similar degree of braiding with a somewhat different channel pattern. A 1944 aerial photograph shows the Gros Ventre channel split as it approaches the confluence with part of the flow following the old channel route and the other part entering at the present confluence location.

Aerial photos from the early 1950's indicate that the river was highly unstable with large areas of exposed gravel upstream of the Gros Ventre River and near the downstream end of the study area. However, downstream of the confluence for about one-half mile the channel was surprising stable with vegetation growing relatively close to the active channel banks. By 1960, levees had been constructed along the left side of the active meander belt. The levees followed a secondary channel, enclosing a 60 acre wooded island at the confluence. Since construction of the levees, there has been a moderate expansion of the active meander belt into the wooded riparian zone to the east. The Snake River progressively eroded the confluence island from both sides. By 1996 more than half of the island had been washed away. Additional erosion occurred in 1997. With a new channel cutting through the center of the island, the remaining trees will probably wash away within a few years.

4.6.4.2 Area 10 Restoration Measures

a. Channel Alignment. Although the channel is highly braided, the main channel has usually followed one or more of several identifiable courses through Area 10. Gravel excavation, debris fences, and a short pilot channel are designed to shift the main channel activity back into existing courses toward the center of the meander belt, taking pressure off of eroding wooded islands to the west and riparian growth along the east bank.

b. Removal of Excess Gravel. Two sites were chosen for gravel removal. The upper site captures gravel before it enters the restoration site; it directs flow down through the center of the braided area in two distinct channels. It is designed to encourage moderate channel entrenchment and increased stability of downstream channels. It should reduce pressure on eastward lands and to allow vegetation to become reestablished on interior islands. The lower site reduces gravel inflow from the Gros Ventre River and should take some pressure off of the eco-fences and remains of the wooded island to the west by drawing the main current toward the center of the excavated area.

c. Eco-Fences. Eco-fences are proposed for use to protect Bear Island and reduce flow into the eastward channel. Other fences near the center of the drawing (Plate 19) will be used to restrict flow into the channel along the west levee alignment and encourage eastward accretion of the adjacent wooded islands. The pilot channel (running through Range 28) will be required to take pressure off of the downstream wooded island area and shift flow back to the center of the meander belt.

d. Pool and Channel Restoration. Restriction of flow along the west levee should encourage revegetation of this corridor and provide opportunities for aquatic habitat enhancement in the small secondary channel that remains. Two pools will be developed in this sheltered area with root wads, and other woody debris added to provide shade and shelter.

e. Spur Dikes. Groups of spur dikes will be located at three points along the levees where sustained high velocities are expected. These dikes will provide velocity diversity and resting areas for fish. They will also strengthen and increase the effectiveness of the adjacent levees.

4.6.5 Summary of Restoration Features by Project Area

The main categories of restoration measures are summarized below in Table 4.6 with indication of which measures are proposed for each project area.

Table 4.6 – Configurations of Management Measures by Study Area

	Gravel Removal			Fences	Barbs	Root Wads	Grade Control
	Channel Capacity	Side Pools	Sediment Traps				
Area 1		X	X	X		X	
Area 4	X	X	X	X	X	X	
Area 9	X	X		X	X	X	X
Area 10	X	X	X	X	X	X	

For each project area, four different designs of fences were evaluated. These designs included three piling eco-fences of different design specifications and one rock fence. The differences in these fence designs are described below.

a. Piling Eco-fences. Several load conditions were used in the design of the piling eco-fence. The load conditions consisted of the following:

- Impact from a floating log on a single pile.
- Impact from a floating log on a cable.
- Static hydraulic head from river flows behind the fence.

The flow velocities used to determine the force for each load condition were 5, 8, and 12 fps. These velocities are representative of the 15-, 25-, and 50-year flood flow velocities. Based on the analyses, piling type, minimum pile penetration depth, and wire rope size were determined. This information is presented in Table 4.7.

Table 4.7 - Piling Sizes

Water Velocity (feet per second)	Piling	Minimum Penetration (feet)
5	Pipe (6" X 0.432")	12
8	H – Pile (8" X 36")	14
12	H – Pile (10" X 42")	16

Other options were considered, such as attaching a synthetic mesh or round timbers to the piling. It was determined that these options do not have the strength to withstand the river forces for the given flow conditions and were eliminated. Timber piling was also considered for piling and was found to be able to withstand the load conditions with velocities up to 5 fps. However, due to the high bedload movement in the river, timber piling was eliminated from further consideration because the timber would rapidly breakdown.

b. Rock Eco-fences. A rock eco-fence design is considered in order to investigate an alternative to a piling eco-fence that would be suitable for withstanding the high river forces. The rock eco-fences will consist of riprap with side slopes of 2 horizontal to 1 vertical and an embedment depth of at least 4 feet below the adjacent ground line. Riprap will be placed to a top elevation of 1 foot below the 100-year flood. Riprap will be sized to meet gradation 4 (Table 4.6).

4.7 Array of Alternatives for Detailed Evaluation

The four different designs of fences, applied with the other features (gravel removal, dikes, root wads, and grade control) at each of the 4 sites resulted in 16 alternatives for detailed evaluation of costs and environmental benefits in the study.

The 16 alternatives are listed in Table 4.8. The column labeled "Description" indicates the design of eco-fence for each alternative.

Table 4.8 – 16 Alternatives for Detailed Evaluation	
Name of Alternative for Analyses	**Description**
Alternative A1	Area 1, 15-year fence design
Alternative A2	Area 1, 25-year piling eco-fence design
Alternative A3	Area 1, 50-year fence design (piling)
Alternative A4	Area 1, 50-year fence design (rock)
Alternative B1	Area 4, 15-year fence design
Alternative B2	Area 4, 25-year fence design
Alternative B3	Area 4, 50-year fence design (piling)
Alternative B4	Area 4, 50-year fence design (rock)
Alternative C1	Area 9, 15-year fence design
Alternative C2	Area 9, 25-year fence design
Alternative C3	Area 9, 50-year fence design (piling)
Alternative C4	Area 9, 50-year fence design (rock)-
Alternative D1	Area 10, 15-year fence design
Alternative D2	Area 10, 25-year fence design
Alternative D3	Area 10, 50-year fence design (piling)
Alternative D4	Area 10, 50-year fence design (rock)

4.8 Cost of Alternatives

This section provides cost estimates for each of the 16 alternatives. Draft MCACES cost estimates were developed for each alternative and are summarized in Section 4.8.1; broken down by: (1) construction costs; (2) real estate; (3) supervisory and administrative costs; (4) preconstruction, engineering, and design (PED) costs; and (5) O&M costs. Construction costs include components for mobilization and demobilization, materials and labor, field and home office overhead, profit, bond, and contingency. One season is assumed for construction at each site. Annual O&M costs were developed for gravel removal, site armoring, eco-fences, anchored root wads, and bank barbs. Annual O&M costs were applied for each year in the 50-year period of analysis is converted to their present value. The following tables summarize the cost estimates for each of the 16 alternatives.

4.8.1 Study Area 1 Cost Estimates

Table 4.9 – Cost Estimate for Area 1		
Cost Estimate for Alternative A1		
Cost Category	*Total*	*Average Annual Equivalent*
Construction Costs	$4,734,300	
Real Estate	286,140	
Supervisory & Administrative (6%)	284,058	
PED (9%)	426,087	
TOTAL FIRST COSTS	5,730,585	$408,687
O&M	5,703,489	406,754
TOTAL COST	$11,434,074	$815,441
Cost Estimate for Alternative A2		
Cost Category	*Total*	*Average Annual Equivalent*
Construction Costs	$4,726,600	
Real Estate	286,140	
Supervisory & Administrative (6%)	283,596	
PED (9%)	425,394	
TOTAL FIRST COSTS	5,721,730	$408,055
O&M	5,687,626	405,623
TOTAL COST	$11,409,356	$813,678
Cost Estimate for Alternative A3		
Cost Category	*Total*	*Average Annual Equivalent*
Construction Costs	$4,795,900	
Real Estate	286,140	
Supervisory & Administrative (6%)	287,754	
PED (9%)	431,631	
TOTAL FIRST COSTS	5,801,425	$413,739
O&M	5,676,584	404,836
TOTAL COST	$11,478,009	$818,574
Cost Estimate for Alternative A4		
Cost Category	*Total*	*Average Annual Equivalent*
Construction Costs	$5,849,300	
Real Estate	286,140	
Supervisory & Administrative (6%)	350,958	
PED (9%)	526,437	
TOTAL FIRST COSTS	$7,012,835	$500,133
O&M	5,714,845	407,564
TOTAL COST	$12,727,680	$907,697

NOTE: Real Estate Costs in this table are based on early estimates; however, subsequent changes do not affect the selection of preferred alternatives.

4.8.2 Study Area 4 Cost Estimates

Table 4.10 – Cost Estimate for Area 4

Cost Estimate for Alternative B1

Cost Category	Total	Average Annual Equivalent
Construction Costs	$10,912,800	
Real Estate	99,720	
Supervisory & Administrative (6%)	654,768	
PED (9%)	982,152	
TOTAL FIRST COSTS	$12,649,440	$902,117
O&M	15,580,390	1,111,143
TOTAL COST	$28,229,830	$2,013,260

Cost Estimate for Alternative B2

Cost Category	Total	Average Annual Equivalent
Construction Costs	$10,906,200	
Real Estate	99,720	
Supervisory & Administrative (6%)	654,372	
PED (9%)	981,558	
TOTAL FIRST COSTS	$12,641,850	$901,576
O&M	15,566,796	1,110,173
TOTAL COST	$28,208,646	$2,011,749

Cost Estimate for Alternative B3

Cost Category	Total	Average Annual Equivalent
Construction Costs	$11,086,300	
Real Estate	99,720	
Supervisory & Administrative (6%)	665,178	
PED (9%)	997,767	
TOTAL FIRST COSTS	$12,848,965	$916,347
O&M	15,557,362	1,109,501
TOTAL COST	$28,406,327	$2,025,847

Cost Estimate for Alternative B4

Cost Category	Total	Average Annual Equivalent
Construction Costs	$11,907,400	
Real Estate	99,720	
Supervisory & Administrative (6%)	714,444	
PED (9%)	1,071,666	
TOTAL FIRST COSTS	$13,793,230	$983,688
O&M	15,587,180	1,111,627
TOTAL COST	$29,380,410	$2,095,316

4.8.3 Study Area 9 Cost Estimates

Table 4.11 – Cost Estimate for Area 9		
Cost Estimate for Alternative C1		
Cost Category	*Total*	*Average Annual Equivalent*
Construction Costs	$2,866,000	
Real Estate	67,680	
Supervisory & Administrative (6%)	171,960	
PED (9%)	257,940	
TOTAL FIRST COSTS	$3,363,580	$239,880
O&M	2,869,853	204,669
TOTAL COST	$6,233,433	$444,548
Cost Estimate for Alternative C2		
Cost Category	*Total*	*Average Annual Equivalent*
Construction Costs	$2,687,600	
Real Estate	67,680	
Supervisory & Administrative (6%)	172,056	
PED (9%)	258,084	
TOTAL FIRST COSTS	$3,185,420	$227,174
O&M	2,871,761	204,805
TOTAL COST	$6,057,181	$431,979
Cost Estimate for Alternative C3		
Cost Category	*Total*	*Average Annual Equivalent*
Construction Costs	$3,052,500	
Real Estate	67,800	
Supervisory & Administrative (6%)	183,150	
PED (9%)	274,725	
TOTAL FIRST COSTS	$3,578,055	$255,175
O&M	2,855,718	203,661
TOTAL COST	$6,443,773	$458,836
Cost Estimate for Alternative C4		
Cost Category	*Total*	*Average Annual Equivalent*
Construction Costs	$3,146,500	
Real Estate	67,680	
Supervisory & Administrative (6%)	188,790	
PED (9%)	283,185	
TOTAL FIRST COSTS	$3,686,155	$262,885
O&M	2,859,113	203,903
TOTAL COST	$6,545,268	$466,787

4.8.4 Study Area 10 Cost Estimates

Table 4.12 – Cost Estimate for Area 10		
Cost Estimate for Alternative D1		
Cost Category	*Total*	*Average Annual Equivalent*
Construction Costs	$5,552,400	
Real Estate	100,920	
Supervisory & Administrative (6%)	333,144	
PED (9%)	499,716	
TOTAL FIRST COSTS	$6,486,180	$462,573
O&M	10,072,638	718,348
TOTAL COST	$16,558,818	$1,180,921
Cost Estimate for Alternative D2		
Cost Category	*Total*	*Average Annual Equivalent*
Construction Costs	$5,563,800	
Real Estate	100,920	
Supervisory & Administrative (6%)	333,828	
PED (9%)	500,742	
TOTAL FIRST COSTS	$6,449,290	$463,508
O&M	10,062,378	717,616
TOTAL COST	$16,561,668	$1,181,124
Cost Estimate for Alternative D3		
Cost Category	*Total*	*Average Annual Equivalent*
Construction Costs	$5,924,000	
Real Estate	100,920	
Supervisory & Administrative (6%)	355,440	
PED (9%)	533,160	
TOTAL FIRST COSTS	$6,913,520	$493,050
O&M	10,055,257	717,108
TOTAL COST	$16,968,777	$1,210,158
Cost Estimate for Alternative D4		
Cost Category	*Total*	*Average Annual Equivalent*
Construction Costs	$6,654,500	
Real Estate	100,920	
Supervisory & Administrative (6%)	39,270	
PED (9%)	598,905	
TOTAL FIRST COSTS	$7,393,595	$527,287
O&M	10,081,771	718,999
TOTAL COST	$17,475,366	$1,246,286

4.9 Environmental Outputs of Alternatives

Two output measures were incorporated into the economic analyses to evaluate the efficiency and effectiveness of the 16 alternatives at achieving environmental restoration objectives: (1) aquatic habitat units; and (2) riparian habitat units. Aquatic habitat units were measured using a model developed for the Jackson Hole study for fine-spotted-cutthroat trout. Riparian habitat units were measured using the USFWS's Habitat Evaluation Procedures palustrine/forest model for the song sparrow. The habitat evaluations indicated significant historic declines in both aquatic and riparian habitat quantity and quality since the 1950s. The habitat evaluations also predicted continued sustained declines in habitat over the 50-year period evaluated.

Table 4.13 - Aquatic Habitat Trends 1998-2050 Without Project

Site	Aquatic Habitat Units				
	1998	*2000*	*2025*	*2050*	*% Change*
Area 1	1,780	1,780	1,739	1,673	(-6%)
Area 4	4,303	4,303	4,181	4,005	(-7%)
Area 9	2,250	2,250	2,190	2,102	(-7%)
Area 10	3,150	3,150	3,067	2,935	(-7%)
All Sites	11,483	11,483	11,177	10,715	(-7%)

Table 4.14 - Riparian Habitat Trends 1998-2050 Without Project

Site	Riparian Habitat Units				
	1998	*2000*	*2025*	*2050*	*% Change*
Area 1	126.9	123.8	85.2	51.2	(-60%)
Area 4	107.8	105.2	72.2	43.1	(-60%)
Area 9	12.7	12.4	8.6	5.3	(-58%)
Area 10	50.6	49.4	34.4	21.2	(-58%)
All Sites	298.0	290.8	200.4	120.8	(-59%)

For each environmental variable, habitat units were estimated for each year in the 50-year period of analysis. The resulting stream of environmental outputs were summed to provide the total output stream with the project, and then divided by the number of years in the period of analysis

(50) to arrive at average annual habitat units for each alternative. The change in habitat units between the without- and with-project conditions was computed for each alternative to be used as the environmental input for the cost effectiveness and incremental cost analyses. The results of these calculations are summarized in the following tables. For each project area (Project Area 1 = Alternative A; Project Area 4 = Alternative B; Project Area 9 = Alternative C; Project Area 10 = Alternative D) data is provided for alternatives 1 through 4, as wall as for the No-Action Alternative (A0, B0, C0, and D0).

Calculations were also conducted to identify the percentage change in habitat units for all alternatives. While the absolute change in habitat figures (column marked "Change") gives the appearance that aquatic benefits are much greater than riparian, the "% Change" figures indicate that in many cases, relative riparian change from the without-project condition is actually greater. The reader is reminded that the two output habitat unit categories were evaluated using different models and, therefore, the habitat units are not directly comparable with one another.

Table 4.15 – Aquatic Habitat Units

Alternative	Without-Project Average Annual Habitat Units	With-Project Average Annual Habitat Units	Change	% Change
A0	1,740.68	1,740.68	00.00	0.0000%
A1	1,740.68	1,786.72	46.04	2.6449%
A2	1,740.68	1,786.72	46.04	2.6449%
A3	1,740.68	1,786.72	46.04	2.6449%
A4	1,740.68	1,786.72	46.04	2.6449%
B0	4,188.8	4,188.8	00.00	0.0000%
B1	4,188.8	4,351.96	163.16	3.8951%
B2	4,188.8	4,351.96	163.16	3.8951%
B3	4,188.8	4,663.96	475.16	11.3436%
B4	4,188.8	4663.96	475.16	11.3436%
C0	2,193.62	2,193.62	00.00	0.0000%
C1	2,193.62	2,317.2	123.58	5.6336%
C2	2,193.62	2,317.2	123.58	5.6336%
C3	2,193.62	2,785.68	592.06	26.9901%
C4	2,193.62	2,785.68	592.06	26.9901%
D0	3,070.52	3,070.52	00.00	0.0000%
D1	3,070.52	3,262.32	191.8	6.2465%
D2	3,070.52	3,262.32	191.8	6.2465%
D3	3,070.52	4,042.8	972.28	31.6650%
D4	3,070.52	4,042.8	972.28	31.6650%

Table 4.16 – Riparian Habitat Units				
Alternative	**Without-Project Average Annual Habitat Units**	**With-Project Average Annual Habitat Units**	**Change**	**% Change**
A0	89.08	89.08	0.00	0%
A1	89.08	185.63	96.54	108%
A2	89.08	191.69	102.61	115%
A3	89.08	225.78	136.70	153%
A4	89.08	225.78	136.70	153%
B0	75.47	74.57	0.00	0%
B1	75.47	106.07	30.60	41%
B2	75.47	109.83	34.36	46%
B3	75.47	128.56	53.09	70%
B4	75.47	128.56	53.09	70%
C0	12.73	12.73	0.00	0%
C1	12.73	13.89	1.16	9%
C2	12.73	14.36	1.64	13%
C3	12.73	16.85	4.12	32%
C4	12.73	16.85	4.12	32%
D0	35.87	35.87	0.00	0%
D1	35.87	58.70	22.82	64%
D2	35.87	60.70	24.82	69%
D3	35.87	71.26	35.38	99%
D4	35.87	71.26	35.38	99%

4.10 Incidental Benefits

Incidental benefits are anticipated to result from the implementation of restoration measures at the sites. These benefits have not been quantified as part of the study, but are identified here to support informed decision making. Anticipated incidental benefits include recreation benefits, flood control benefits, and reductions in existing operation and maintenance requirements for the existing flood control levee system in the proposed project area. Without further analysis and quantification of these incidental benefits, it is assumed that the benefits consistently result from each of the 16 alternatives.

a. Recreation. Potential incidental recreation benefits include higher-valued recreation experiences and opportunities in the proposed project area, including rafting and boating as well as recreational fishing. Increased fishing opportunities in the area are not expected to be in conflict with the project purpose of environmental restoration. Prevailing fishery management practices include slot limits to allow takings from only portions of the stocks which are in

abundance, and the prevailing culture of recreational fisherman supports catch-and-release practices to support minimization of human impacts. Quantification of incidental recreation benefits for each alternative would require further study.

b. Flood Control. It is expected that the restoration measures under consideration have no significant impacts on flood control benefits provided by the existing Federal flood control project. It is anticipated that there may be small localized flood control benefits in the immediate vicinity of project sites resulting from increased channel capacity from gravel removal. Quantification of incidental localized flood control benefits for each alternative would require further study.

c. Operation and Maintenance. It is anticipated that implementation of restoration features will have the incidental effect of reducing existing O&M expenditures for the existing Federal levee system. Currently, low-flow channels can impinge on the inside of the levees, requiring the placement of armoring to protect the levees form erosion. Because the restoration features propose to train the river away from the levees, it is expected that reductions in O&M requirements will result. Quantification of incidental reductions in O&M costs for the existing Federal flood control project for each alternative would require further study.

4.11 Cost Effectiveness and Incremental Cost Analyses

The cost and output information presented in the previous two sections is the input for cost effectiveness and incremental cost analyses to evaluate the relative effectiveness and efficiency of the different alternatives at producing environmental outputs. Because two different and incommensurate output measures (aquatic and riparian habitat units) were required to assess the holistic effect of alternatives at restoring diverse ecosystem values, two separate analyses were conducted. Each analysis examines the production efficiency of the alternatives for each environmental output category. Following the presentation of results for each environmental category, a comparison is made to identify alternatives that exhibit exceptional performance for both output categories.

To conduct the analyses, the procedures identified in the Corps procedures manual for conducting cost effectiveness and incremental cost analyses (*IWR Report #95-R-1*, USACE, May 1995) were followed. These steps include: (1) display costs and outputs of alternatives; (2)

identify combinable alternatives; (3) derive combinations and calculate costs and outputs; (4) identify cost-effective plans; (5) calculate and display most efficient alternatives through incremental cost analysis. To facilitate the analysis, the Corps software program, IWR-PLAN was used to perform the above steps. The results of the steps are summarized below. First, the analysis for aquatic habitat is presented, followed by the analysis for riparian habitat.

4.11.1 Aquatic Habitat Cost Effectiveness and Incremental Cost Analyses

Table 4.17 provides a display of the costs and outputs associated with each alternative. Both cost and output data are presented as "Average Annual."

Table 4.17 – Aquatic Habitat: Costs and Outputs for All Alternatives

Alternative	Average Annual Cost ($)	Average Annual Aquatic Habitat Units
A0	$0	0.00
A1	815,441	46.04
A2	813,678	46.04
A3	818,574	46.04
A4	907,697	46.04
B0	0	0.00
B1	2,013,260	163.16
B2	2,011,749	163.16
B3	2,025,847	475.16
B4	2,095,316	475.16
C0	0	0.00
C1	444,548	123.58
C2	431,979	123.58
C3	458,836	592.06
C4	466,787	592.06
D0	0	0.00
D1	1,180,921	191.80
D2	1,181,124	191.80
D3	1,210,158	972.28
D4	1,246,286	972.28

The IWR-PLAN software was used to formulate all possible combinations of alternatives for restoring aquatic habitat, resulting in 625 possible combinations of alternatives called plans (including the no-action plan). Cost effectiveness analysis was next performed to identify those combinations of alternatives that (1) produce the same output as other combinations for less cost,

or (2) produce more output than others at the same or less cost. The result was the reduction of the 625 possible combinations to 10 cost-effective combinations (including the no-action plan). Table 4.18 displays the cost-effective plans with their costs and outputs.

Table 4.18 – Aquatic Habitat: Cost-Effective Combinations

Plan	Cost ($)	Output
A0+B0+C0+D0	$0	0
A0+B0+C1+D0	431,979	123.58
A0+B0+C3+D0	458,836	592.06
A0+B0+C0+D3	1,210,158	972.28
A0+B0+C1+D3	1,642,137	1,095.86
A0+B0+C3+D3	1,668,994	1,564.34
A2+B0+C3+D3	2,482,672	1,610.38
A0+B2+C3+D3	3,680,743	1,727.50
A0+B3+C3+D3	3,694,841	2,039.50
A2+B3+C3+D3	4,508,519	2,085.54

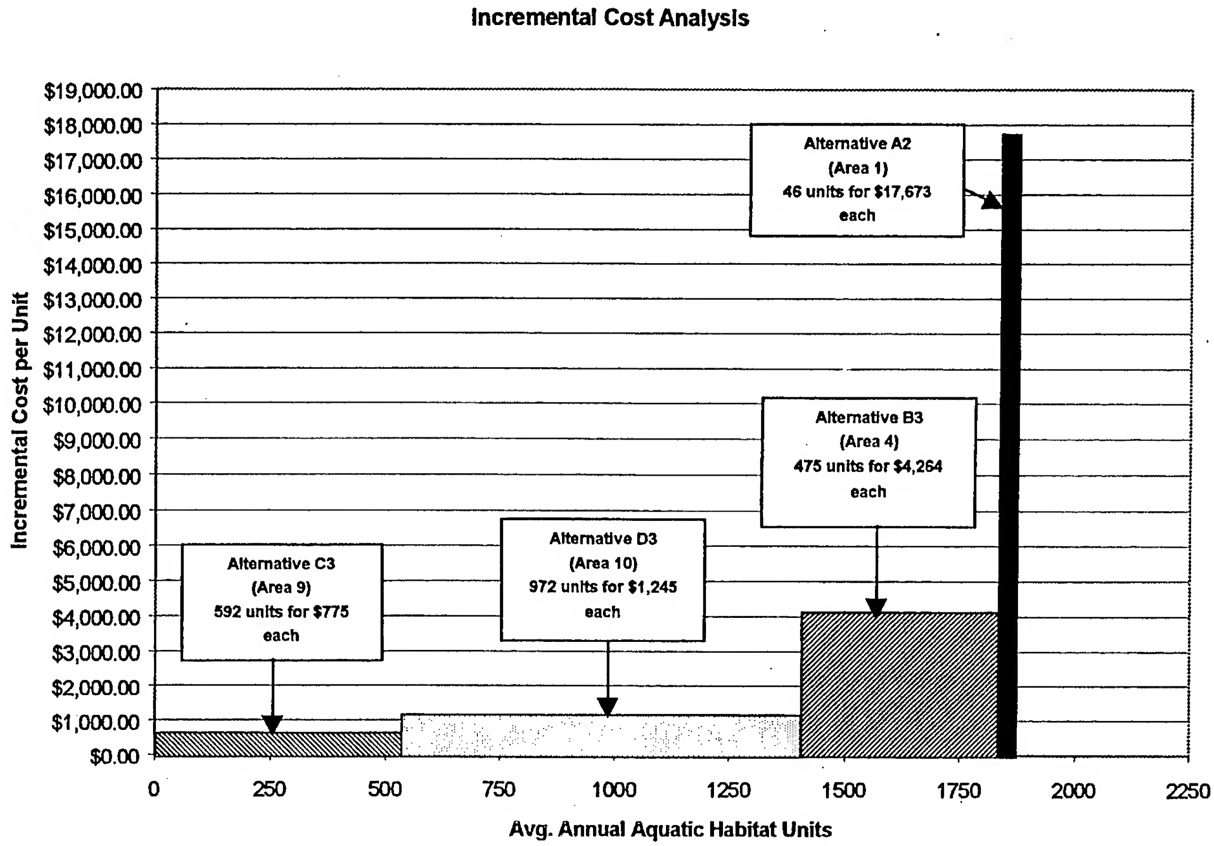
An incremental cost analysis was then conducted to evaluate the changes in cost and output from the no-action plan to all other cost-effective plans. The change in cost associated with each plan was divided by the change in output to determine the incremental cost per unit. The incremental cost per unit reflects the unit cost of providing additional output over the no-action plan. The plan that is identified as having the lowest unit cost of providing additional habitat is sometimes called the best-buy. This best-buy becomes the new baseline to which all larger-output-producing plans are compared to identify the next-best-buy. This iterative process results in the identification of the most efficient set of plans for producing increasing levels of output. The incremental cost analysis identified five best-buy plans (including the no-action plan).

Table 4.19 – Aquatic Habitat: Incremental Cost Analysis (Best-Buys)

Plan	Cost ($)	Output	Change in Cost ($)	Change in Output	Incremental Cost per Unit ($)
A0+B0+C0+D0	$0.00	0	--	--	--
A0+B0+C3+D0	458,836.00	592.06	$458,836.00	592.06	$775
A0+B0+C0+D3	1,668,994.00	1,564.34	1,210,158.00	972.28	1,245
A0+B3+C3+D3	3,694,841.00	2,039.50	2,025,847.00	475.16	4,264
A2+B3+C3+D3	4,508,519.00	2,085.54	813,678.00	46.04	17,673

The data in Table 4.19 can be interpreted to support the recommendation of a plan for producing aquatic habitat. If aquatic habitat units are desired, the most efficient alternative available is C3, which provides 592 average annual habitat units at a unit cost of $775 each. If more output is desired, the next most efficient alternative is to add D3, which provides 972.28 additional average annual habitat units at a unit cost of $1,245 each. If more output is desired, the next most efficient alternative is to add B3, which provides 475 additional average annual habitat units at a unit cost of $4,264 each. If more output is desired, the next most efficient alternative is to add A2, which provides 46 additional average annual habitat units at a unit cost of $17,673 each.

The following figure provides a graphical representation of the data in Table 4.19. Incremental cost per unit is plotted on the vertical axis and output along the horizontal axis. The graph shows relatively small increases in incremental cost per unit from the first alternative (C3) to the next (D3). The increase in incremental cost per unit is larger from D3 to B3, but not as large as the jump in cost to get the last 46 units of output provided by A2.



4.11.2 Riparian Habitat Cost Effectiveness and Incremental Cost Analyses

Table 4.20 provides a display of the costs and outputs associated with each alternative. Both cost and output data are presented as "Average Annual."

Table 4.20 – Riparian Habitat: Costs and Outputs for All Alternatives

Alternative	Average Annual Cost ($)	Average Annual Riparian Habitat Units
A0	$0	0.00
A1	815,441	96.54
A2	813,678	102.61
A3	818,574	136.70
A4	907,697	136.70
B0	0	0.00
B1	2,013,260	30.60
B2	2,011,749	34.36
B3	2,025,847	53.09
B4	2,095,316	53.09
C0	0	0.00
C1	444,548	1.16
C2	431,979	1.64
C3	458,836	4.12
C4	466,787	4.12
D0	0	0.00
D1	1,180,921	22.82
D2	1,181,124	24.82
D3	1,210,158	35.38
D4	1,246,286	35.38

The IWR-PLAN software was used to formulate all possible combinations of alternatives for restoring riparian habitat, resulting in 625 possible combinations of alternatives called plans (including the no-action plan). Cost effectiveness analysis was next performed to identify those combinations of alternatives that (1) produce the same output as other combinations for less cost, or (2) produce more output than others at the same or less cost. The result was the reduction of the 625 possible combinations to 26 cost-effective combinations (including the no-action plan). Table 4.21 displays the cost-effective plans with their costs and outputs.

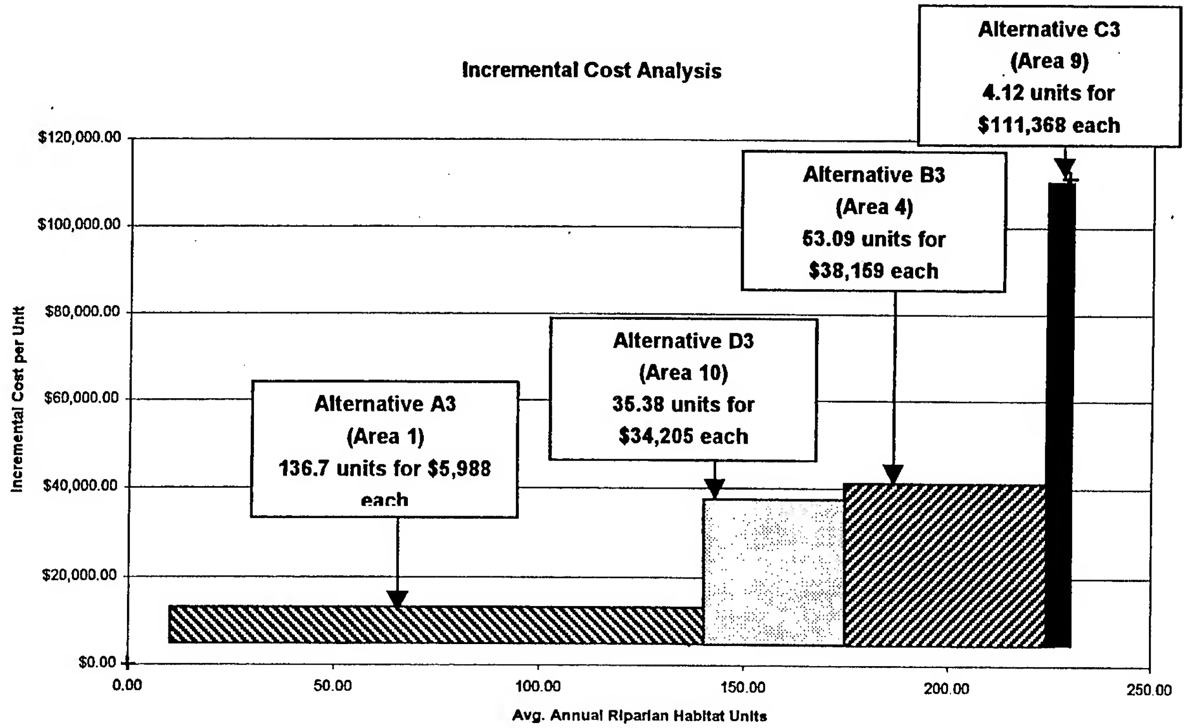
Table 4.21 – Riparian Habitat - Cost Effective Combinations		
Plan	**Cost $**	**Output**
A0+B0+C0+D0	$0	0.00
A0+B0+C2+D0	431,979	1.64
A0+B0+C3+D0	458,836	4.12
A2+B0+C0+D0	813,678	102.61
A3+B0+C0+D0	818,574	136.70
A3+B0+C2+D0	1,250,553	138.34
A3+B0+C3+D0	1,277,410	140.82
A3+B0+C0+D1	1,999,495	159.52
A3+B0+C0+D2	1,999,698	161.52
A3+B0+C0+D3	2,028,732	172.08
A3+B0+C2+D3	2,460,711	173.72
A3+B0+C3+D3	2,487,568	176.20
A3+B3+C0+D0	2,844,421	189.79
A3+B3+C2+D0	3,276,400	191.43
A3+B3+C3+D0	3,303,257	193.91
A3+B2+C0+D2	4,011,447	195.88
A3+B3+C0+D1	4,025,342	212.61
A3+B3+C0+D2	4,025,545	214.61
A3+B3+C0+D3	4,054,579	225.17
A3+B3+C2+D3	4,486,558	226.81
A3+B3+C3+D3	4,513,415	229.29

An incremental cost analysis was then conducted to evaluate the changes in cost and output from the no-action plan to all other cost-effective plans. The change in cost associated with each plan was divided by the change in output to determine the incremental cost per unit. The incremental cost per unit reflects the unit cost of providing additional output over the no-action plan. The plan that is identified as having the lowest unit cost of providing additional habitat is sometimes called the best-buy. This best-buy becomes the new baseline to which all larger-output-producing plans are compared to identify the next-best-buy. This iterative process results in the identification of the most efficient set of plans for producing increasing levels of output. The incremental cost analysis identified five best-buy plans (including the no-action plan).

Table 4.22 – Riparian Habitat: Incremental Cost Analysis (Best-Buys)					
Plan	**Cost ($)**	**Output**	**Change in Cost ($)**	**Change in Output**	**Incremental Cost per Unit ($)**
A0+B0+C0+D0	$0	0.00	--	--	--
A3+B0+C0+D0	818,574	136.70	$818,574	136.70	$5,988
A3+B0+C0+D3	2,028,732	172.08	1,210,158	35.38	34,205
A3+B3+C0+D3	4,054,579	225.17	2,025,847	53.09	38,159
A3+B3+C3+D3	4,513,415	229.29	458,836	4.12	111,368

The data in Table 4.22 can be interpreted to support the recommendation of a plan for producing riparian habitat. If riparian habitat units are desired, the most efficient alternative available is A3, which provides 136.70 average annual habitat units at a unit cost of $5,988 each. If more output is desired, the next most efficient alternative is to add D3, which provides 35.38 additional average annual habitat units at a unit cost of $34,205 each. If more output is desired, the next most efficient alternative is to add B3, which provides 53.09 additional average annual habitat units at a unit cost of $38,159 each. If more output is desired, the next most efficient alternative is to add C3, which provides 4.12 additional average annual habitat units at a unit cost of $111,368 each.

The figure on the following page provides a graphical representation of the data in Table 4.22. Incremental cost per unit is plotted on the vertical axis and output along the horizontal axis. The graph shows a large return for investment with A3 (Area 1), then a jump in incremental cost per unit to get to the next alternatives (B3 and D3), which each provide significant output for similar incremental cost per unit. A significant increase in incremental cost per unit comes as Alternative C3 is implemented. This is largely due to the relatively small change in riparian output with the alternative. While C3 ranks last in riparian habitat production efficiency, this is in large part due to the riparian habitat demonstration project that has already been completed at Area 9 and factored into the without-project analysis. Further examination should be conducted to determine if implementing the aquatic habitat restoration features at Area 9 would provide for sustainability of benefits to be provided by the Area 9 demonstration project.



4.12 Cross-Comparison of Aquatic and Riparian Costs and Benefits

Because the project required two analyses, one for aquatic restoration and one for riparian restoration, a comparison of results was conducted to identify any plans that may be particularly effective and efficient at producing both types of outputs. This comparison is summarized in Table 4.23. Table 4.23 lists the alternatives that were found to be best-buys for either output type. For each alternative, cost, aquatic habitat units, riparian habitat units, and incremental cost per unit for both habitat types are presented. In addition the table indicates whether each alternative was found to be (1) cost-effective for either habitat type, and (2) a best-buy for either habitat type. In the columns that identify if alternatives were determined to be best-buys, a number in parentheses indicates the rank of the best-buy. Fo. example, a 1 indicates that the alternative was the most efficient at producing that output type, a 2 was the next most efficient, and so on.

Table 4.23 – Cross-Comparison of Aquatic and Riparian Costs and Benefits

Evaluation Criteria	Alternative				
	D3 (Area 10)	B3 (Area 4)	C3 (Area 9)	A3[1] (Area 1)	A2[1] (Area 1)
Avg. Annual Cost	$1,210,158	$2,025,847	$458,836	$818,574	$813,678
Avg. Annual Aquatic Output	972.28	475.16	592.00	46.04	46.04
Inc. Cost per Unit of Aquatic	$1,244	$4,263	$775	--	$17,673
Avg. Annual Riparian Output	35.38	53.09	4.12	136.70	102.61
Inc. Cost per Unit of Riparian	$34,205	$38,159	$111,368	$5,988	--
Cost-Effective for Aquatic	X	X	X		X
Cost-Effective for Riparian	X	X	X	X	
Best-Buy for Aquatic (Rank out of 4)	X(2)	X(3)	X(1)	--	X(4)
Best-Buy for Riparian (Rank out of 4)	X(2)	X(3)	X(4)	X(1)	--

(1) Alternative A3 was identified as the first best-buy for riparian but was found to be non-cost effective for aquatic because A2 provided the same aquatic output as A3 for approximately $5,000 less. Due to the closeness in cost of A3 and A2, and A2s A2 is set aside and A3 is carried forward for possible recommendation.

4.13 Uncertainty Analysis

To examine the effect of uncertainty in cost and output estimates, an analysis was conducted that evaluated the implications of 20 percent uncertainty in cost estimates and 20 percent uncertainty in output estimates. All cost and output estimates for all 625 possible combinations were adjusted to reflect plus and minus 20 percent. A best-case scenario using the minus 20 percent adjusted cost estimates and the plus 20 percent adjusted output estimates was then analyzed for both aquatic and riparian output types. Similarly, a worst-case scenario was analyzed using plus 20 percent adjusted cost estimates and minus 20 percent adjusted output estimates. The results of these sensitivity analyses provided very similar results to those presented in the previous sections. In both the best- and worst-case scenarios, the ranking of best-buys was the same as described in the previous section, indicating that data uncertainty in the plus or minus 20 percent range should not have a significant impact on the results.

4.14 Initially Proposed NER Plan Recommendation

(See also Section 4.16 for a progressive approach.)

Based upon the cost effectiveness and incremental cost analyses and the comparison of aquatic and riparian costs and benefits, Alternative D3 at Area 10 stood out as the most efficient option for producing combined habitat types, ranking second in efficiency for riparian habitat and second for aquatic. Alternative B3 at Area 4 is recommended as it is the third most efficient for riparian and the third most efficient for aquatic. Alternative A3 at Area 1 is clearly the most efficient for riparian but is the least efficient for aquatic. Similarly, Alternative C3 at Area 9 is the most efficient for aquatic although it is the least efficient for riparian. Both these sites are recommended for incorporation into a holistic ecosystem restoration plan for the study area based upon the results of the cost effectiveness analysis. The economic analysis supports the recommendation of plan A3+B3+C3+D3 as the initially proposed National Ecosystem Restoration Plan (NER Plan) for the Jackson Hole study. This plan corresponds to Area 1, 50-year fence design (piling), Area 4, 50-year fence design (piling), Area 9, 50-year fence design (piling), and Area 10, 50-year fence design (piling). Table 4.24 summarizes the information on the initially proposed NER Plan.

Table 4.24 – Initially Proposed NER Plan Cost and Output Summary

Alternative		Total Cost ($)	Average Annual Cost ($)	Total O&M (included in Total Cost) ($)	Average Annual O&M Cost (included in Avg. Annual Cost) ($)	Total Real Estate Cost (included in Total Cost) ($)	Average Annual Aquatic Output	Average Annual Riparian Output
A3	Area 1, 50-year fence design (piling)	$11,478,009	$818,574	$5,676,584	$404,836	$286,140	46.04	136.7
B3	Area 4, 50-year fence design (piling)	28,406,327	2,025,847	15,557,362	1,109,501	99,720	475.16	53.09
C3	Area 9, 50-year fence design (piling)	6,443,773	458,836	2,855,718	203,661	67,800	592.06	4.12
D3	Area 10, 50-year fence design (piling)	16,968,777	1,210,158	10,055,257	717,108	100,920	972.28	35.38
A3+B3+C3+D3		$63,296,886	$4,513,415	$34,144,921	$2,435,106	$554,580	2,085.54	229.29

As presented in Table 4.24, the NER Plan for the *Feasibility Study* has an estimated total cost of $63,296,886, or an average annual equivalent cost of $4,513,415. This total cost includes $34,144,921 in total O&M costs over the project life (an average annual equivalent value of $2,435,106 per year, and a total real estate cost of $554,580. The plan is estimated to provide an additional 2,086 aquatic habitat units over the without-project condition (an increase 18.5 percent from the without-project condition). The plan is also estimated to provide an additional 229 riparian habitat units (an increase of 107.6 percent from the without-project condition).

4.15 Value Engineering / Initially Proposed NER Plan Refinement

Following identification of the initially proposed NER Plan, the Walla Walla District and the sponsor agreed with the recommendation and also with the need to evaluate opportunities to refine the project and O&M procedures in areas that may lead to cost savings without reducing project performance. In response, the Walla Walla District study team conducted a value engineering exercise to refine the plan's preliminary cost estimate and examine, identify, and incorporate cost savings into project construction, operation and maintenance. This section identifies the changes to the NER Plan resulting in cost savings and evaluates the impact of such changes on plan formulation.

Savings were identified in three primary areas:

- Reductions in component quantities.
- Reductions in construction cost.
- Reductions in O&M cost.

4.15.1 Refinement of Quantities

The NER Plan includes restoration alternatives for Areas 1, 4, 9, and 10 (see Plates 4, 16 through 19). Plan elements include gravel removal, site armoring, piling eco-fence, anchored root wads, and riprap structures such as kickers, bank barbs, and grade controls. Approximate quantities for the major components of the NER Plan are summarized in Table 4.25. Changes in quantities from those used in the preliminary estimate to those used in the refined estimate are indicated in the table.

As indicated in the table, the major reductions in quantities come in the area of gravel removal estimated to be required for excavation of sediment traps and stabilization of the channel. There is a net decrease (across all sites) in the quantities required for armoring and spur dikes. Quantities estimated for eco-fences, anchored root wads, and rock grade control are not changed in the refined estimates.

Table 4.25 – Initially Proposed NER Plan Quantities Refinement

Location	Quantity Estimate	Gravel Removal	Armoring	Eco-Fences	Root Wads	Spur Dikes	Rock Grade Control
Area 1	Preliminary	419,400	46,600	7,600	440	0	0
	Refined	334,000	66,800	7,600	440	200	0
	Change	-85,400	20,200	0	0	200	0
Area 4	Preliminary	1,062,790	118,080	6,100	320	1,700	0
	Refined	371,800	74,360	6,100	320	200	0
	Change	-690,990	-43,720	0	0	-1,500	0
Area 9	Preliminary	234,000	26,000	650	250	2,550	3,300
	Refined	130,000	26,000	650	250	2,550	3,300
	Change	-104,000	0	0	0	0	0
Area 10	Preliminary	528,530	58,730	4,800	180	4,250	0
	Refined	293,600	58,730	4,800	180	4,250	0
	Change	-234,930	0	0	0	0	0

4.15.2 Refinement of Unit Costs

All reductions in unit costs in the refined cost estimates are attributable to the identification of a closer disposal site for dredged material. Initial cost estimates for disposal of dredged material were based upon use of a disposal site located approximately 12 miles from the proposed project sites. A closer disposal facility was identified approximately 5 miles from the project sites, reducing disposal costs. Other unit costs remained unchanged from the preliminary estimates.

4.15.3 Refinement of Operation and Maintenance Costs

Due to concerns about the high cost of annual maintenance following initial construction of the project, the requirements for gravel removal were revisited. The preliminary estimates reflected

the maximum reasonable expected requirements based upon the available information at that time. Subsequent sediment range resurveys indicated that the actual gravel requirement is likely much less than the original estimate (reflected in the refinement of construction quantities, Section 4.15.1) and may be zero after some years at one or more of the proposed restoration sites. Based upon this new information, the costs for removal of gravel for channel capacity and sediment traps was reduced to more accurately reflect actual expected values over the project life. This reduction in annual maintenance requirements resulted in significant cost corrections for project operation and maintenance.

Table 4.26 – Refined O&M Quantities

			Annual O&M Percentage		Annual O&M Quantities	
		Construction Quantity	Years 1-5	Years 6-50	Years 1-5	Years 6-50
AREA 1	Gravel removal	334,000	13%	7%	43,420	23,380
	Armoring	66,800	13%	7%	8,684	4,676
	Fences	7,600	2%	4%	152	304
	Root wads	440	20%	20%	88	88
	Spur dikes	200	N/A.	N/A.	N/A.	N/A.
	Rock grade control	0	13%	14%	0	0
			Annual O&M Percentage		Annual O&M Quantities	
		Construction Quantity	Years 1-5	Years 6-50	Years 1-5	Years 6-50
AREA 4	Gravel removal	371,800	13%	9%	48,334	33,462
	Armoring	74,360	13%	9%	9,667	6,692
	Fences	6,100	2%	4%	122	244
	Root wads	320	20%	20%	64	64
	Spur dikes	200	N/A	N/A	N/A	N/A
	Rock grade control	0	13%	14%	0	0
			Annual O&M Percentage		Annual O&M Quantities	
		Construction Quantity	Years 1-5	Years 6-50	Years 1-5	Years 6-50
AREA 9	Gravel removal	130,000	13%	5%	16,900	6,500
	Armoring	26,000	13%	5%	3,380	1,300
	Fences	650	2%	4%	13	26
	Root wads	250	20%	20%	50	50
	Spur dikes	2,550	N/A	N/A	N/A	N/A
	Rock grade control	3,300	13%	14%	429	462
			Annual O&M Percentage		Annual O&M Quantities	
		Construction Quantity	Years 1-5	Years 6-50	Years 1-5	Years 6-50
AREA 10	Gravel removal	293,600	13%	10%	38,168	29,360
	Armoring	58,730	13%	10%	7,635	5,873
	Fences	4,800	2%	4%	96	192
	Root wads	180	20%	20%	36	36
	Spur dikes	4,250	N/A	N/A	N/A	N/A
	Rock grade control	0	13%	14%	0	0

4.15.4 Summary of Initially Proposed NER Plan Refined Costs

Table 4.26 presents the effects on summary cost categories of the value engineering cost refinements in the areas of construction quantities, unit costs, and O&M quantities.

Table 4.26.A – Initially Proposed NER Plan Refined Cost Estimate Summary					
Alternative		First Cost (Construction, Real Estate, PED, S&A)	O&M	Total Cost	Average Annual Cost
A3	Area 1, 50-year fence design (piling)	8,083,000	2,515,194	10,598,194	755,829
B3	Area 4, 50-year fence design (piling)	8,616,000	2,967,328	11,583,328	826,085
C3	Area 9, 50-year fence design (piling)	3,417,000	1,061,610	4,478,610	319,400
D3	Area 10, 50-year fence design (piling)	6,858,000	2,353,597	9,211,597	656,941
A3+B3+C3+D3		26,974,000	8,897,729	35,871,729	2,558,255

Table 4.26.B – Initially Proposed NER Plan Preliminary Cost Estimate Summary					
Alternative		First Cost (Construction, Real Estate, PED, S&A)	O&M	Total Cost	Average Annual Cost
A3	Area 1, 50-year fence design (piling)	5,801,425	5,676,584	11,478,009	818,574
B3	Area 4, 50-year fence design (piling)	12,848,965	15,557,362	28,406,327	2,025,847
C3	Area 9, 50-year fence design (piling)	3,588,055	2,855,718	6,443,773	458,836
D3	Area 10, 50-year fence design (piling)	6,913,520	10,055,257	16,968,777	1,210,158
A3+B3+C3+D3		29,151,965	34,144,921	63,296,886	4,513,415

Table 4.26.C – Change in Cost Estimates Summary					
Alternative		First Cost (Construction, Real Estate, PED, S&A)	O&M	Total Cost	Average Annual Cost
A3	Area 1, 50-year fence design (piling)	+ $2,281,575	- $3,161,390	- $879,815	- $62,745
B3	Area 4, 50-year fence design (piling)	-4,232,965	-12,590,034	-16,822,999	-1,199,762
C3	Area 9, 50-year fence design (piling)	-171,055	-1,794,108	-1,965,163	-139,436
D3	Area 10, 50-year fence design (piling)	-55,520	-7,701,660	-7,757,180	-553,217
A3+B3+C3+D3		- $2,177,965	- $25,247,192	- $27,425,157	- $1,955,160

Table 4.26.A summarizes the refined cost estimates for each component of the NER Plan as well as for the NER Plan as a whole. Table 4.26.B summarizes the cost estimates described in

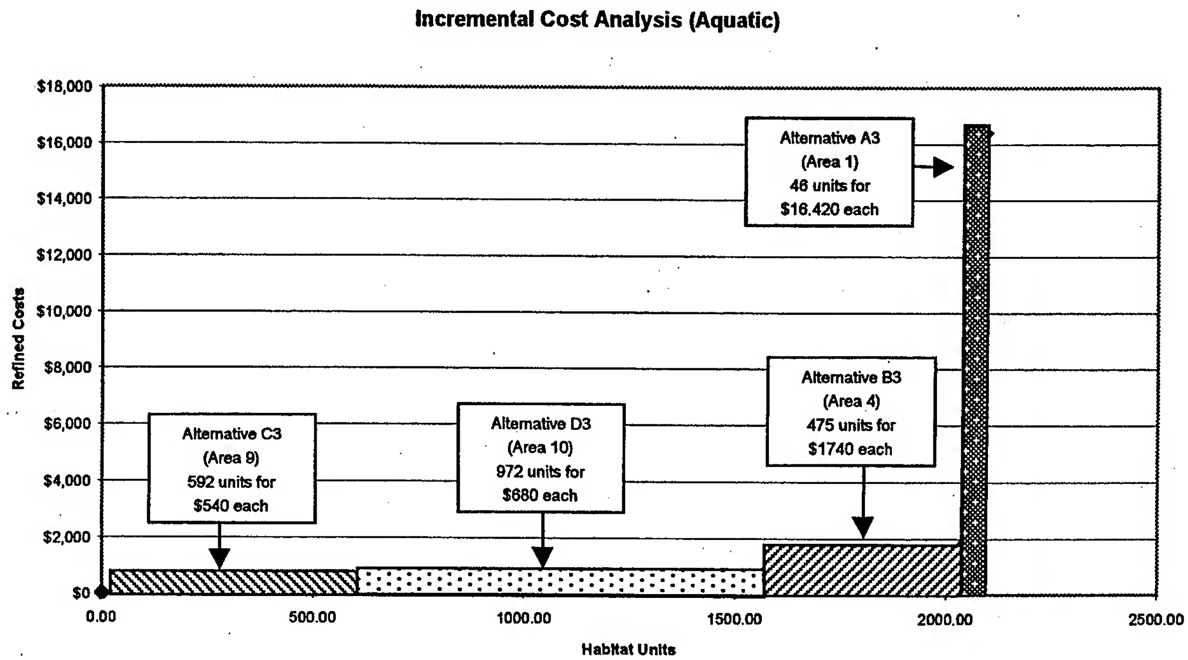
Section 4, Plan Formulation. Table 4.26.C summarizes the change in cost from the preliminary estimates to the refined estimates. Table 4.26.C shows the reductions in each cost component for the NER Plan to be as follows:

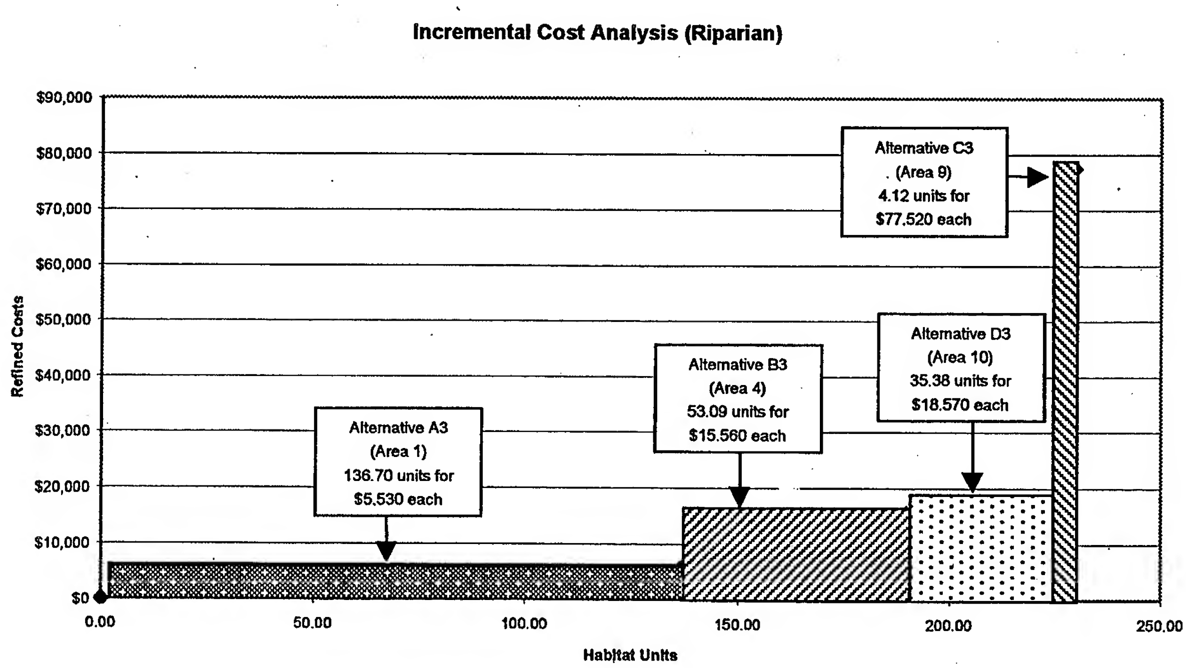
- Construction, PED, and Supervisory/Administrative changed by -$2,177,965.
- O&M Costs changed by -$25,247,192.
- Total Costs changed by -$27,425,157.
- The average annual equivalent value of total costs changed by -$1,955,160 per year.

4.15.5 Impact of Cost Reductions on Plan Formulation

Because of the significant reductions in the initially proposed NER Plan's cost (as identified in Section 4.15.4) the study team assessed the impacts of the refined costs on the plan formulation process documented in earlier parts of Section 4. It was determined that the cost reductions would have no impact on the selection of Design Alternative 3 (differentiated by the 50-year piling eco-fence) at each of the sites because the cost reductions would apply consistently to all alternatives at each site. Therefore, the rationale for selecting Alternative 3 at each site would hold in a new cost effectiveness and incremental cost evaluation.

However, the reductions in cost were determined to have differing impacts on the different study areas (for example, a significant change in construction costs was tied to the identification of a closer site for disposal of dredged material. As some study areas require more excavation than others, this change would affect different sites inconsistently. To assess the impact on formulation of the NER Plan, an analysis was conducted to determine the relative cost effectiveness of the individual components of the NER plan (A3, B3, C3, and D3) with the refined costs estimates. The results of the new incremental cost analyses for each output type (aquatic and riparian) are presented in graphs on the following page. A discussion of the reductions in incremental cost and the impacts on formulation of the NER Plan follow the incremental cost graphs.


Incremental Cost Analysis (Aquatic)
Refined Costs
$18,000
$16,000
$14,000
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$0
0.00
500.00
1000.00
1500.00
2000.00
2500.00
Habitat Units
Alternative A3 (Area 1) 46 units for $16,420 each
Alternative B3 (Area 4) 475 units for $1740 each
Alternative C3 (Area 9) 592 units for $540 each
Alternative D3 (Area 10) 972 units for $680 each


Incremental Cost Analysis (Riparian)
Refined Costs
$90,000
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$0
0.00
50.00
100.00
150.00
200.00
250.00
Habitat Units
Alternative C3 (Area 9) 4.12 units for $77,520 each
Alternative D3 (Area 10) 35.38 units for $18,570 each
Alternative B3 (Area 4) 53.09 units for $15,560 each
Alternative A3 (Area 1) 136.70 units for $5,530 each

4.15.5.1 Refined Aquatic Cost Analysis

The incremental cost analysis for restoration of aquatic habitat produced the same sequence of recommended components with the refined costs as with the preliminary costs. The amount of output provided remained constant while the incremental cost per unit decreased across the board. As with the earlier analysis using preliminary costs, the most efficient option was identified as C3 (Area 9). Alternative C3 provides 592 habitat units at an annual unit cost of $540 each. This unit cost is down from $775 each with the preliminary estimate. The second most efficient alternative in both analyses (using preliminary and refined estimates) was D3 (Area 10). D3 provides 972 habitat units at an annual unit cost of $680 each (down from the unit cost of $1,245 each with the preliminary cost estimates). Next in the efficiency rankings in both analyses was B3 (Area 4). B3 provides 475 habitat units at an annual unit cost of $1,740 each (down from a unit cost of $4,264 each with the preliminary cost estimates). Ranking last in efficiency for restoring aquatic habitat was Alternative A3 (Area 1), which provides 46 additional habitat units at an annual unit cost of $16,420 each (down from $17,673 with the preliminary cost estimates). The percentage reduction in incremental unit costs are summarized below:

- Area 9 (Alternative C3) — Incremental unit cost reduced by 30 percent.
- Area 10 (Alternative D3) — Incremental unit cost reduced by 45 percent.
- Area 4 (Alternative B3) — Incremental unit cost reduced by 60 percent.
- Area 1 (Alternative A3) — Incremental unit cost reduced by 7 percent.

Based upon these results there is no impact of using the refined costs that changes the results of the formulation of the NER Plan based upon aquatic incremental cost evaluations.

4.15.5.2 Refined Riparian Cost Analysis

The incremental cost analysis for restoration of riparian habitat produced a similar sequence of recommended components with the refined costs as with the preliminary costs. The amount of output provided remained constant while the incremental cost per unit decreased across the board. As with the earlier analysis using preliminary costs, the most efficient option was identified as A3 (Area 1). Alternative A3 provides 136.70 habitat units at an annual unit cost of $5,530 each. This unit cost is down from $5,988 each with the preliminary estimate. The

second most efficient alternative in both analyses (using preliminary and refined estimates) was B3 (Area 4). B3 provides 53.09 habitat units at an annual unit cost of $15,560 each (down from the unit cost of $38,159 each with the preliminary cost estimates). Next in the efficiency rankings in both analyses was D3 (Area 10). D3 provides 35.38 habitat units at an annual unit cost of $18,570 each (down from a unit cost of $34,205 each with the preliminary cost estimates). Ranking last in efficiency for restoring aquatic habitat was Alternative C3 (Area 9), which provides 4.12 additional habitat units at an annual unit cost of $77,520 each (down from $111,368 with the preliminary cost estimates). The percentage reduction in incremental unit costs are summarized below:

- Area 1 (Alternative A3) Incremental unit cost reduced by 7 percent.
- Area 4 (Alternative B3) Incremental unit cost reduced by 60 percent.
- Area 9 (Alternative D3) Incremental unit cost reduced by 45 percent.
- Area 10 (Alternative C3) Incremental unit cost reduced by 30 percent.

The cost effectiveness rankings of B3 and D3 were reversed, but the relative increase in incremental cost between the two is reasonable and both are recommended. Based upon these results there is no impact of using the refined costs that changes the results of the formulation of the NER plan based upon riparian incremental cost evaluations.

4.16 The Progressive Plan

4.16.1 Plan Recommendation

The Corps conducted this feasibility study of the Snake River near Jackson Hole, Wyoming, from August 1996 to January 2000. An alternative formulation briefing was held in July 1999, and the study results (pending resolution of several issues) were approved for public release with concurrent HQUSACE review. At that time, the proposed project covered approximately 5 miles of the 22-mile stretch of the Snake River that had been authorized for study.

During a site visit in October 1999, Headquarters staff recommended that the District Project Manager consider using the cost and benefit information gathered for the 5-mile study area (presented in this report as the initially proposed NER Plan) as a proxy for the entire 22-mile

reach. The rationale is that the applicable engineering measures had already been identified, the benefits of the management measures had been evaluated, and the construction costs had been developed. Therefore, the District could use the site-specific information to formulate a complete plan to restore the entire degraded area. The complete plan developed by the district is presented as the "Progressive Plan" in this report.

4.16.2 Plan Formulation of the Progressive Plan

At the point that the initially proposed NER Plan was formulated, the feasibility study had conducted five levels of plan refinement: (1) significance based preliminary screening; (2) formulation of initial alternatives; (3) cost effectiveness and incremental cost analyses; (4) uncertainty analysis and value engineering; and (5) NER plan refinement. The sixth level of analysis used to address the entire 22-mile reach of the Snake River is based on the refined cost and benefits of Areas 1, 4, 9, and 10. In order to select restoration tools and features for the Progressive Plan, the study team analyzed recent aerial photographs, floodplain cross-sectional data, and results of the sponsor-constructed demonstration project as represented in the *Final Report: Snake River Restoration Demonstration Project*, prepared by Teton Conservation District (included in the Supplementary Section of this study). Table 4.27 presents the configuration of restoration measures for the Progressive Plan.

Table 4.27 – Configurations of Management Measures by Study Area: Progressive Plan

	Gravel Removal			Fences	Barbs	Root Wads	Grade Control
	Channel Capacity	Side Pools	Sediment Traps				
Area 1		X	X	X		X	
Area 4	X	X	X	X	X	X	
Area 9	X	X	X	X	X	X	X
Area 10	X	X	X	X	X	X	
Area A	X	X	X	X	X	X	
Area B	X	X	X	X	X	X	
Area C	X	X	X	X	X		
Area D	X	X	X	X	X	X	
Area E	X				X	X	
Area F	X			X	X	X	
Area G	X	X		X	X	X	
Area H	X	X		X	X	X	

In addition, a new project cost estimate was developed based on a progressive project construction and monitoring plan. This approach takes into consideration the complexity of the restoration effort and applies an efficiency curve that represents the anticipated benefits of adaptive management. The progressive estimate assumes that the cumulative knowledge of construction, adaptive management, and monitoring will result in cost reduction. The approach resulted in a significant reduction in total project cost and reduces monitoring costs to 4 percent of the total project cost. The first site constructed would be phased over a 6-year period to allow refinement and fine tuning of restoration features. The construction period would then be reduced for each consecutive area until a three-year construction phase is reached. Table 4.28 illustrates the construction and monitoring phasing and provides project cost by area, and details Federal, non-Federal, and fully funded cost.

JACKSON HOLE ENVIRONMENTAL RESTORATION PROJECT
CONSTRUCTION & MONITORING and COST TIMELINE

Project Cost

KEY: Construction (schedule and cyds): SS — Continuing Construction (schedule and cyds): $$ — Monitoring:

Areas	FY 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
9	73	2,712											-	-	-	-	-	-	-	-	$ 4,306
			259	267	276	285	294														
1	-	698	6,137										-	-	-	-	-	-	-	-	$ 9,628
				589	608	628	649														
4	-	-	797	6,566									-	-	-	-	-	-	-	-	$ 9,716
					656	678	700														
10	-	-	-	636	5,387								-	-	-	-	-	-	-	-	$ 7,338
						529	547														
B	-	-	-	-	589	5,117								-	-	-	-	-	-	-	$ 6,726
							394	407													
D	-	-	-	-	-	509	4,629								-	-	-	-	-	-	$ 5,799
								232	[illegible]												
F	-				-	-	545	4,782								-	-	-	-	-	$ 6,010
									240	248											
A	-				-	-	-	546	3,786								-	-	-	-	$ 5,082
										289	299										
G	-				-	-	-	-	459	3,848								-	-	-	$ 4,855
											192	199									
H	-	-	-	-	-	-	-	-	-	400	2,678										$ 3,454
												131	136								
C	-	-	-	-	-	-	-	-	-	-	294	2,098								-	$ 2,687
													104	106							
E	-	-	-	-	-	-	-	-	-	-	-	213	617								$ 897
														21	22						
Total	$ 73	$ 3,410	$ 7,193	$ 8,058	$ 7,516	$ 7,746	$ 7,758	$ 6,171	$ 4,972	$ 5,070	$ 3,787	$ 2,997	$ 1,041	$ 289	$ 164	$ 107	$ 75	$ 44	$ 22	$ 5	$66,498

Estimated Project Cost based on Construction Schedule

Cost Share

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Govt	$ 47	$ 2,216	$ 4,675	$ 5,238	$ 4,885	$ 5,035	$ 5,043	$ 4,011	$ 3,232	$ 3,296	$ 2,462	$ 1,948	$ 677	$ 188	$ 106	$ 70	$ 49	$ 28	$ 14	$ 3	
Running Total		$ 2,264	$ 6,939	$ 12,177	$ 17,062	$ 22,097	$ 27,140	$ 31,151	$ 34,383	$ 37,678	$ 40,140	$ 42,088	$ 42,765	$ 42,953	$ 43,059	$ 43,129	$ 43,178	$ 43,206	$ 43,221	$ 43,224	
Sponsor	$ 26	$ 1,193	$ 2,517	$ 2,820	$ 2,631	$ 2,711	$ 2,715	$ 2,160	$ 1,740	$ 1,775	$ 1,326	$ 1,049	$ 364	$ 101	$ 57	$ 38	$ 26	$ 15	$ 8	$ 2	
Running Total		$ 1,219	$ 3,736	$ 6,557	$ 9,187	$ 11,898	$ 14,614	$ 16,773	$ 18,514	$ 20,288	$ 21,614	$ 22,663	$ 23,027	$ 23,129	$ 23,186	$ 23,223	$ 23,250	$ 23,265	$ 23,273	$ 23,274	$66,498

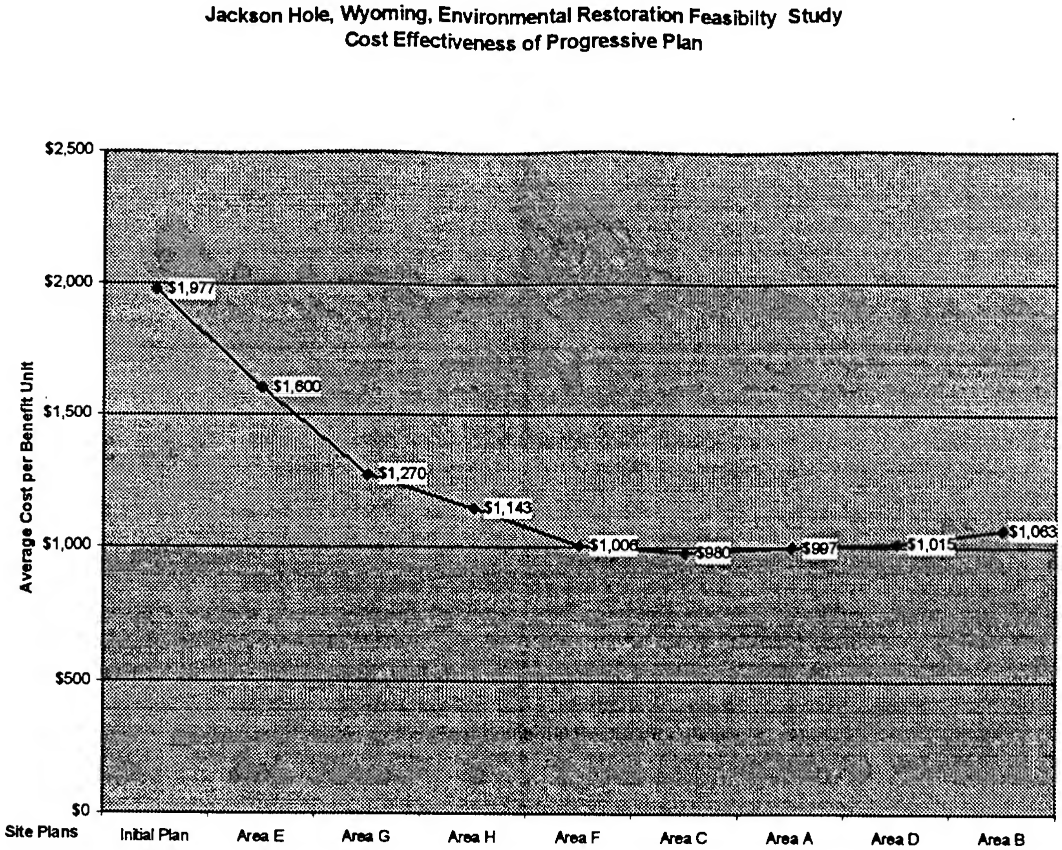
4.16.3 Cost Effectiveness and Incremental Analysis

The IWR-PLAN software was used to formulate all possible combinations of alternatives for restoring aquatic and riparian habitat for the Progressive Plan. Areas A through H were compared with the areas studied in formulation of the initially proposed NER Plan. Cost effective analysis was next performed to identify those combinations of alternatives that produce the same output as other combinations for less cost, or produce more output than others at the same or less cost. Table 4.29 displays the cost-effective alternatives with their costs and outputs. The table illustrates the reduced cost to be realized with the larger, progressive restoration plan.

Table 4.29 – Incremental Analysis: Progressive Plan

	Equivalent Annual Costs ($1,000)	Annual Benefit Units	Average Cost per Benefit Unit ($1,000)	Cumulative Annual Cost ($1,000)	Cumulative Annual Benefit Units	Cumulative Average Cost per Benefit Unit
Initial NER Plan	$4,577	2,315				$1,977
Area E	81	596	$136	$4,658	2,911	1,600
Area G	575	1,209	476	5,233	4,120	1,270
Area H	395	806	490	5,628	4,926	1,143
Area F	747	1,411	529	6,375	6,337	1,006
Area C	300	477	629	6,675	6,814	980
Area A	749	634	1,181	7,424	7,448	997
Area D	737	596	1,237	8,161	8,044	1,015
Area B	1,066	634	1,681	9,227	8,678	1,063

The following figure provides a graphical representation of the data in Table 4.29



4.16.4 Plan Summary

Based upon the cost effectiveness and incremental cost analysis the Progressive Plan is recommended for construction. This plan builds upon the efficiencies gained in the initially proposed NER plan (Areas 1, 4, 9, and10) and leads to greater efficiencies for the remainder of the impacted 22-mile reach of the Snake River. The Progressive Plan reduces average cost per benefit units starting with Area E at $1,600 each to Area G at $1,270, to Area H at $1,143, to Area F at $ 1,006 to Area C at $980 before increasing slightly in Area A to $997, Area D at $1,015 to Area B at $ 1,063 (see Table 4.30). The economic analysis supports the recommendation of the Progressive Plan as the proposed NER Plan for the Jackson Hole study area. Table 4.30 summarizes the information on the proposed Progressive Plan.

Table 4.30-Progressive Plan Cost and Output Summary (2001 dollars)								
($1,000)								
Alternative	TPC Total Construction Cost (2001 Base Year)	IDC	TIC	Annual Investment Costs	Annual O&M Costs	Total Annual Costs	Average Annual Aquatic Outpug	Average Annual Riparian Output
A3 Area 1	$8,839	$2,609	$11,448	$737	$586	$1,323	46.04	136.70
B3 Area 4	8,706	2,003	10,709	698	789	1,487	475.16	53.09
C3 Area 9	4,029	1,419	5,448	344	217	561	592.06	4.12
D3 Area 10	6,412	1,068	7,480	493	714	1,207	972.28	35.38
Area A	3,909	672	4,581	303	446	749	570.19	63.71
Area B	5,698	967	6,665	440	626	1,066	570.19	63.71
Area C	1,880	331	2,211	147	153	300	473.65	3.30
Area D	4,767	828	5,595	370	367	737	592.06	4.12
Area E	613	117	730	49	32	81	592.06	4.12
Area F	4,783	832	5,615	372	375	747	1361.19	49.53
Area G	3,620	631	4,251	282	293	575	1166.73	42.46
Area H	2,495	441	2,936	195	200	395	777.82	28.30
Total NER Plan	$55,751	$11,917	$67,668	$4,429	$4,797	$9,227	8,189.40	488.50

Definitions: Base Budget Year = 2001, price level at October 1, 2000.
TPC = Total Project Cost = Construction costs, lands, PED, construction management, and monitoring costs.
IDC = Interest During Construction = Time value of construction investment dollars.
Total Annual Costs = AAE Costs = Amortized present value of lifetime costs at discount rate of 6.875%, over 50 year project life and/or total average annual equivalent cost of total investment and total O&M costs.
Annual Benefit Output over project life of 50 years for both aquatic and riparian units.
Total may not be exact due to rounding.

5. DESCRIPTION OF INITIALLY PROPOSED NER PLAN AND THE PROGRESSIVE NER PLAN

5.1 NER Plan Benefits Simulation

The overall effect of the proposed NER Plan is best shown in the computer-generated oblique aerial views of the without- and with-project conditions at Area 9. Plate 20 shows the existing condition (looking downstream) of the Snake River between the levees. The channel is largely devoid of vegetation, which is confined to islands located near the left bank levee. In the future, without-project condition (Plate 21) the flows between the levees will continue to rework the gravels in the channel and will remove all but a few very small remnants of the currently existing islands.

Plate 22 shows the with-project condition immediately after construction. Here eco-fences are placed on the right side of the vegetated island to the left-center of the view and anchored root wads are placed on the upstream edges of the unvegetated island in the center of the view. Channel capacity excavations are visible in the main channel and secondary channels are excavated between islands on the left. Spur dikes are added to protect the right-bank levee from impinging flows and to train the current more toward the center of the channel.

In the near future, 5 to 15 years hence, sediment is trapped and vegetation has begun to establish along the fences and root wads (Plate 23). Twenty years hence, vegetation has increased and is reinforcing the islands (Plate 24). Fifty years hence, the vegetation is fully matured and well established (Plate 25). Throughout the project life, flow capacity in the main channel as well as the secondary channels will be maintained by periodic gravel removal. Elements of the overall restoration plan are described in Section 5.2 below.

5.2 NER Plan Features

5.2.1 Piling Brush Eco-Fences

Eco-fences block, slow down, or deflect the force of the river current during high-flow periods in order to protect existing islands and vegetation and cause deposition of sediment where new vegetation may become established. Eco-fences allow the river to heal itself. Rather than the costly and disruptive process of placing fine sediments with heavy equipment, the river will be allowed to do the work through a natural process. See Plates 16 through 19 for general eco fence locations.

Eco-fences will be placed at the upstream end and along the sides of existing wooded islands to prevent or inhibit further soil and vegetation loss. These fences will also be placed in areas where soil and vegetation have already been lost to facilitate deposition and vegetation regrowth (Plate 30). As vegetation becomes established, it will further slow flow velocities and encourage accelerated sedimentation. Indirect aquatic habitat benefits will be gained as vegetation is reestablished (Plate 31). As the amount of vegetation increases (Plate 32), shade and material (such as leaves and insects that fall into the river, providing nutrients to river organisms) will also increase while ensuring future availability of large woody debris in to the river.

Two different types of fences: piling eco-fences and rock eco-fences, may be used. Piles will be driven and have interconnecting cables attached. Rock eco-fences, constructed of riprap, will require excavation to key the structure into the cobble, gravel, and sand substrate. Excavated material will be scooped and transported off site for upland disposal. Riprap will be trucked to the site and dumped directly into the excavations. Riprap used to construct the rock eco-fences will be large, angular rock, free of fine sediment.

5.2.2 Secondary Channels

Secondary channels, also referred to as side channels, are typically smaller channels, which parallel the main river channel (see Plate 27). Secondary channels vary in size and depth and may carry flows year-round or only during periods of high water. These channels help disperse flows and suspended sediments throughout the floodplain; they provide valuable aquatic habitat.

Secondary channels will be constructed in selected locations to improve flows to existing off-channel pools or provide flows to newly constructed pools. See Section 5.2.5 for discussion of off-channel pools. Some secondary channels exist within the leveed sections of the river. However, because of accelerated flows, these existing channels are degraded or plugged. Gravel and cobble will be excavated to either enhance existing secondary channels or to construct new channels.

Because of the remote locations and potential disturbances to wetland and riparian vegetation by trucks accessing the excavation sites, dredged cobble, gravel, and sand will either be scooped and side-cast on the adjacent gravel deposits or transported from the site for upland disposal. The determination of whether to side-cast material or transport it from the site will be based upon the potential impacts of ingress and egress of trucks to the site. If dump truck access routes having minimal disturbance upon vegetation are available, the material will be scooped and transported to a permitted gravel processing facility for disposal. Excavated gravel and cobble may be screened, depending upon the proximity of the site to the gravel screening area and anticipated need for +4 inch cobbles to rearmor excavation sites. Side-cast material will be uniformly spread on adjacent unvegetated gravel deposits below the ordinary high-water mark in the dry and above the low flow of the river. Fine sediments such as silts and sands will be placed in locations to promote riparian habitat restoration.

5.2.3 Gravel Removal

Gravel removal will be used to varying degrees in the implementation of the various environmental restoration tools to provide more channel stability and provide sediment deposition in controlled areas. Principally gravel removal will be used to improve fish habitat, compensate for reductions in channel capacity, increase channel stability, and improve sediment transport. Gravel removal will be used to construct channel stabilization pools, secondary channels, and off-channel pools. It will also be removed from specific areas of the channel to compensate for the decreases in channel capacity. All gravel removal will be accomplished using a track-mounted excavator, rubber-tired backhoe, or other similar equipment along with trucks to transport the material to disposal and stockpile sites.

Areas (from which gravel is removed to maintain channel capacity and to construct channel stabilization pools and off-channel pools) will be rearmored on the bottom surface using cobbles

screened from the excavated material. Gravels, which are removed, will be either transported to a site located between the levees for screening or will be transported as unscreened material to an existing gravel processing facility off site. Screening will separate out cobbles +4 inch in diameter or larger for use as armoring material. It may be necessary to temporarily stockpile the screened material.

The -4 inch material will be transported from the screening location by truck for off-site upland disposal prior to anticipated high flows. The +4 inch cobble will be transported by dump truck from the screening site to the channel capacity, side pool, and channel stabilization pool excavation sites and placed to rearmor the disturbed bed. The material will be dumped in wind-row fashion, perpendicular to the normal stream flow to allow subsequent high flows to naturally disperse the material. The +4 inch cobble will be placed prior to anticipated high flows.

5.2.4 Channel Capacity Excavations

Channel capacity excavation will be used to offset reductions resulting from construction of the environmental restoration tools and effects of the tools upon channel structure and function. Additionally, channel capacity excavation will compensate for ongoing channel aggradation and loss of channel capacity. Channel capacity will be reduced by the installation of anchored root wad logs; discharge of riprap to construct rock eco-fences, spur dikes, and rock grade control; and from the deposition of bedload material and resultant regeneration of vegetation. Bedload deposition will be intentionally triggered by structures such as the eco-fences and anchored root wad logs. Channel capacity excavations will be necessary to compensate for the effects of the environmental restoration project and maintain the 100-year base flow for flood protection (see Plate 26).

5.2.5 Channel Stabilization Pools

Channel stabilization pools reduce flow velocity, catch bedload material, and reduce the transport of bedload material to downstream areas, which may already have an over abundance of material. These functions improve channel stability and may improve fish habitat through the creation of a large pool. Channel stabilization pools will be excavated in strategically selected locations to trigger the deposition of bedload material and sediments.

5.2.6 Off-Channel Pools

Off-channel pools provide important rearing habitat for cutthroat trout. Access to potential spawning areas in spring creeks and secondary channels and pools has been severely reduced by construction of the levees. This lack of adequate spawning habitat is considered a major limiting factor for cutthroat trout in the Snake River.

Off-channel pools will be constructed within the alignment of the secondary channels to provide rearing habitat for cutthroat trout (Plate 28). Some existing pools will be used and may only require limited excavation to enhance their function. Other pools will require complete excavation. Excavated cobble, gravel, and sand will be either scooped and side-cast on the adjacent gravel deposits or transported from the site for upland disposal. Depending upon the proximity of the site to the gravel screening area and anticipated need for +4 inch cobbles, the excavated gravel may be screened. Side-cast material will be uniformly spread. Side-casting will occur below the ordinary high-water mark in the dry, and above the low flow of the river.

The determination of whether to side-cast material or transport it from the site will be based upon the potential impacts of ingress and egress of trucks to the site and the opportunity to enhance riparian habitat as described above. If dump truck access routes that have a minimal disturbance on vegetation are available, the material will be scooped and transported to a permitted gravel processing facility for disposal.

5.2.7 Spur Dikes

Spur dikes will provide areas of resting habitat close to areas of high velocity, which may transport high quantities of aquatic insects used as food by cutthroat trout and other species and provide protection against bank erosion. Spur dikes will be installed in areas where stream velocity is normally too high for fish to spend much time. These resting areas may be further enhanced with the incorporation of large woody debris on the downstream side. The large woody debris will be placed in areas of ineffective flow.

Spur dikes consist of a series of either kickers or bank barbs extending into the channel from the adjoining levee (Plate 29). Riprap used to construct the spur dikes will consist of large angular rock, free of fines. It is likely that spur dike construction will require in-water work. Both

kickers and bank barbs will be composed of riprap armor. Kickers may extend as much as 60 feet from the levee. Random fill excavated to embed the kickers will be used as the core material. Equipment used to excavate for the kickers and to place riprap will sit atop the levee and will maneuver onto the top of kickers, when necessary. Bank barbs, which are smaller than kickers, will extend up to 30 feet into the channel from the levee. Both types of structures will be embedded into the levee.

5.2.8 Anchored Root Wad Logs

Anchored root wad logs consist of tree trunks with the root attached. Depending on placement, anchored root wad logs may provide additional resting habitat for cutthroat trout and other fish species. The 1989 Jackson Hole Debris Clearance Environmental Assessment found that "local scour and fill is also evident adjacent to woody debris left in the channel following the 1986 flood." Anchored woody debris may also encourage sediment deposition and help establish new vegetation (Plate 33).

Anchored root wad logs will be obtained from along the river channel within the four project areas or from commercial sources. Logs will be transported to the installation site by truck, rubber-tired skidder, or helicopter. A backhoe may be used to level an area to place the logs so that the logs would have uniform bearing along the trunk and its root would be partially embedded. The logs will be fastened down with toggle bolt anchors. The anchors will be driven into the ground with a jackhammer and a jack will be used to pull up on the anchors locking them into place. The cable will be tied around the logs and cinched down to tighten the logs to the ground.

5.2.9 Rock Grade Control

Rock grade control structures keep the river from eroding and destroying existing riparian areas. Riprap will be placed at specific areas where down-cutting of the channel threatens channel stability. Existing cobble, gravel, and sand will be removed to a standard uniform depth of 3 feet below the ground surface. The material will be scooped and transported off site for upland disposal. This area will then be graded and refilled with riprap to match existing topography. Riprap will be transported to the site by truck, dumped, and spread using the anchor track-

mounted excavator. Riprap used to construct the rock grade control will be large angular rock, free of fine sediments.

5.3 Monitoring and Maintenance

Monitoring will be conducted during construction to ensure compliance with various requirements identified in Appendix H, Environmental Assessment, which contains its own Appendix A, Biological Assessment (BA) and Appendix B, Fish and Wildlife Coordination Act Report (CAR). Monitoring will also be conducted following completion of construction to assess changes to aquatic and terrestrial habitat; to identify effects of river flows on the structures, as well as effects of the structures on the river; and to identify the need for structure maintenance. Monitoring procedures for structure integrity and function and for aquatic and terrestrial habitat changes have been identified in a Monitoring Plan.

5.3.1 Monitoring Plan

The purpose of the Monitoring Plan is to assess the effectiveness of the restoration features on aquatic and terrestrial resources. The plan will serve to ensure compliance during construction and assess functional performance of the restoration tools and effects on aquatic and terrestrial habitat. Monitoring will also include the implementation of any project modifications, repairs, or added features that may be necessary for any unforeseen circumstances that may impair project performance, and may include the fine-tuning of project operation to improve overall effectiveness during the effective period of the Monitoring Plan. An annual report summarizing observed damage, required repairs, and observed physical and environmental resource changes associated with the various restoration features will be prepared.

The Monitoring Plan will be in effect for 5 years following the completion of construction at each site. The plan is provided in full as Appendix F to the Environmental Assessment (Appendix H to this study). The cost associated with the monitoring program will be included as part of the construction cost estimate for the project, and will be shared with the local sponsor in accordance with the cost-sharing requirements specified for project implementation. The Monitoring Plan has an estimated total cost of $1,691,000 for the full 5-year program. Results obtained through monitoring will enable the Corps of Engineers and local sponsor, through coordination with local

agencies, regulatory authorities, landowners, and other interests, to make informed decisions concerning management of the project to obtain planned performance. The Monitoring Plan will also build an information base to support future restoration decisions regarding the design and performance of the restoration measures.

5.3.2 Project Maintenance

At the end of the monitoring period, and upon receipt of the O&M manual, the local sponsor will assume normal OMRR&R responsibility for the project, which may include longer-term monitoring to be conducted as part of the local sponsor's O&M responsibilities. Such future requirements will be funded entirely by the local sponsor.

During the first few years of use, an elevated level of maintenance is expected until the system stabilizes and information is gathered that may identify more efficient uses of structures. Certain structures are likely to require maintenance to ensure they continue to function as designed. The shifting nature of the braided river is expected to have some effect upon the structures; however, the extent of effects will vary between structures and from site to site depending upon river conditions. Some structures may require only minor maintenance while others might require more substantial reconstruction. The frequency with which maintenance may be necessary and the extent of necessary repairs will be dictated by the frequency and extent of river effects upon the structures. Maintenance will likely be necessary to maintain and ensure the proper function of eco-fences, secondary channels, channel stabilization pools, spur dikes, and off-channel pools. Maintenance is not expected to be necessary on the remaining environmental restoration tools; however, monitoring will be necessary to assess the need for maintenance.

It is unlikely that vegetative growth from the environmental restoration project will adversely impact flood control. The channel typically has adequate room to adjust its location and conveyance. This is particularly true if the channel alignment is stabilized and excessive erosion is reduced. The designated mid-channel pool areas will provide a means of maintaining adequate conveyance by removing excessive gravel before it has an opportunity to build up in the channel. However, it will be important to assure that "maintenance" does not involve activities that progressively increase the cross-sectional area of protected vegetation at any point along the channel beyond that indicated in the original design drawings.

Maintenance of environmental restoration tools will be conducted in accordance with the limitations and restrictions of the EA (Appendix H) and its appendixes. The local sponsor may be responsible for acquiring some state or local permits necessary to implement maintenance.

5.3.2.1 Eco-Fences

Maintenance measures for the eco-fences should provide for minimal adjustment of fence lengths or alignment, repair of damaged cables or piling, and reestablishment of the fence tie-off to the bankline if erosion damage threatens to destroy the function of the fence, increase bank erosion, or threaten adjacent flood control structures. This could involve removal of some portions of fence if it proved to be poorly aligned or improperly located.

Maintenance will most likely be necessitated by failed posts and fencing or by erosion around the landward end of the fence. Repairs will involve reestablishment of the fence tie-off by extending the fence back to the undisturbed bankline, repositioning existing piles and cable, installing longer posts, reattaching the cables, or adding other material to trap debris. In some cases, it might be sufficient to drive and attach additional supporting posts in locations where the fence is beginning to sag or fail. Work will be done during low flows.

Depending upon how the river affects the fence site, maintenance work may or may not occur in the water. If a fence is failing to catch debris, trapping efficiency might be increased by adding a finer mesh screen that will capture smaller debris, or exposed areas may be covered by dragging some of the debris over to places where it is deficient. If debris is failing to be trapped or is being deflected around the fence, it may be necessary to add one or more fence panels oriented upstream near the end of each fence. In some areas, adjustments in the location or angle of eco-fences may be needed if the river abandons the channel.

5.3.2.2 Secondary Channels

The deposit of gravel and subsequent blockage of the upper end of the channel would necessitate maintenance. If groundwater is inadequate, the secondary channels will need to be reopened to provide an adequate inflow of water for the downstream pools. Gravel blockages will be

excavated sufficiently to provide 2 to 3 (cfs) flow. Excavated gravel will be side-cast due to the anticipated small quantity.

5.3.2.3 Channel Stabilization Pools

The quantity of sediment being transported downstream cannot be precisely calculated and is expected to vary from year to year. Because of this, the optimum size of channel stabilization pools, and their anticipated effectiveness, is not known. Removal of gravel from channel stabilization pools (*i.e.*, sediment traps) as part of O&M will generally occur when one-half or more of the original gravel volume of the pool is refilled. Only about 50 percent of the original pool area will need to be disturbed to remove the quantity necessary to maintain the trap. Excavation will not vary from or exceed the original design. The pools will have to be closely monitored to ensure excessive excavation does not occur. Under average conditions, several years may be necessary to fill a channel stabilization pool; however, it is possible that a single flood event could fill one completely. Experience over time will determine the appropriate level of maintenance.

5.3.2.4 Off-Channel Pools

Off-channel pools will be subject to refilling during high-flow seasons. Pools that are close to the main channel could be refilled with gravel and cobbles in a single high-flow season. Those farther away will likely last a number of years, refilling with silt and sand brought in by the interconnecting channels and by general overbank flow during high-flow periods. Due to the braided nature of the river, it is nearly impossible to select locations where pools would always be protected from potential destruction by major flood flows or channel changes. Based on this, various approaches to maintaining off-channel pools will be used.

Pools near the margins of the active meander belt will be allowed to fill completely. A new pool will then be constructed nearby, without disturbing the old pool or its water supply. Where possible, the new pools will be built either upstream or downstream of the existing pools in order to use the same supply channels. Pools constructed near the main channel in the vegetation-free areas of the channel will be reexcavated only when completely filled with gravel. These channels could be filled in completely during a major event, which could also involve major changes in the main channel. The main channel may even cut a course through the center of a

pool. In the latter case, the pool will be reexcavated at another location (probably along the previously abandoned channel). The objective will be to approximately maintain the same area of pools throughout the life of the environmental restoration project either by re-excavation at the same location or relocation of a pool to a more advantageous site. Maintenance will be performed during the low-flow period.

5.3.2.5 Spur Dikes

Spur dikes will occasionally be damaged by high flows. Measurements, taken at various locations on the existing channel, indicate that erosion can extend down to at least 15 feet below the high-water level. The mode of damage most likely to occur will be undercutting of the toe of the dike and collapse of material into the void with material being transported downstream. Maintenance of bank barbs or kickers will generally involve reestablishment of the toe and restoration to the original geometric outline. Maintenance could include placement of additional bank or toe protection, strategic placement of boulders or intermediate barbs to break up the undesirable flow pattern if undesirable flow patterns are created. In a worst-case scenario, the spur dike group can be removed. It is anticipated that a staged construction sequence will allow design adjustments to be made as experience is gained from the performance of these structures.

5.4 Real Estate

The real estate needs described below are for the initially proposed NER Plan and thus reference Areas 1, 4, 9, and 10. Real estate requirements for the Progressive Plan will occur during the PED phase for each specific additional site. Real estate requirements, such as coordination, easements, and assignments will be conducted with property owners and the BLM. No new requirements are anticipated beyond those addressed in Appendix F, Real Estate or in this section of the Study (Section 5.4). Unforeseen requirements will be carried out by the non-Federal sponsor in coordination with the Corps. This proposed environmental restoration project will occur upon privately owned lands and lands administered by the BLM. Lands will be altered through the removal of gravel and placement of materials to construct the environmental restoration tools. These alterations, however, would not eliminate any current land uses identified above or introduce any new land uses. The local sponsor will obtain real estate

instruments, which the sponsor identifies in their real estate report as being necessary for implementation of environmental restoration work on Federal and private lands.

5.4.1 Ownership Data

Property ownership and estimated individual tract requirements within each of the project areas are shown in Appendix F, Real Estate, and summarized below. In some instances there are multiple parcels located within the proposed sites that are under single ownership. In those cases, each parcel will be treated individually with site-specific easement language.

Area 1 — Encompasses an area of approximately 360 acres. Given the current location of the thread of the active river along the west edge of the floodplain, four ownerships are recognized as being affected by the proposed project. Two private ownerships and one public ownership (BLM) are located within the site, and one private ownership will be affected by access to the site.

Area 4 — Includes approximately 157 acres within nine riparian ownership's ranging from 4 to 32 acres. Six of the parcels are from 13 to 32 acres, the other four are smaller.

Area 9 — Includes approximately 89 acres within 1 riparian ownership's ranging from 0.5 to 70 acres. Seven of the parcels are from 0.5 to 1.5 acres. One BLM tract is 70 acres.

Area 10 — Includes about 335 acres within 13 ownership's ranging from 1 to 65 acres per tract with 8 parcels 10 to 65 acres and 7 ranging from 1 to 9 acres each.

Areas A-H — Real Estate requirement to be conducted during the PED phase prior to construction.

5.4.2 Real Estate Requirements

Real estate requirements are based upon site maps with restoration features located given the existing geomorphology as of the year the aerial photos were taken and do not necessarily represent the actual projects.

a. <u>Existing Easements</u>. To the maximum extent possible, the Federal Government and the non-Federal sponsor will use existing easements to implement the restoration project. However, in most cases the physical boundary limitations of the existing flood control easements do not completely encompass the areas required for the proposed project, therefore additional easements will be required.

b. <u>Additional Easement</u>. Where restoration features are proposed for a parcel where an easement does not exist or is insufficient, an appropriate easement for ecosystem restoration will be procured by the sponsor on a willing-seller basis. The easement will be for the purpose of restoring the Snake River's natural environment, and will be crafted to acquire only the rights needed for the particular restoration features to be located on that particular parcel.

For parcels on which access rights do not exist or are insufficient, the non-Federal sponsor will acquire a road easement estate if required for permanent access. For temporary access, rights will be acquired under a temporary work area easement or temporary road easement.

c. <u>Special Requirements</u>. The BLM is the land manager on three parcels within the initially proposed NER Plan restoration areas. The BLM does not currently have a land management plan in place for the land along the Snake River. Application for a free use permit will be required if bedload material is to be excavated. For planning purposes, it is estimated that ecosystem restoration easements will need to be acquired on approximately 34 parcels from 37 landowners. For Areas 1, 4, 9 and 10, the BLM will require free use permits on 3 parcels. Additional easements for sites A-H are anticipated to have similar requirements.

Teton County is the land manager in one of the proposed restoration areas and has regulatory authority over gravel extractions. Upon initiation of the project, a comprehensive extraction permit would be sought from the County to cover all of the proposed extractions within the project scope. Plans providing the excavation details will be delivered to the Teton County Planning Office and held for review by the planning staff.

The Wyoming Department of Transportation has a maintenance easement at the Jackson-Wilson Bridge which lies within one of the proposed restoration areas. While no permits are required, an excavation plan which involves this area should be sent to the Resident Engineer for review.

d. Real Estate Requirements by Area. The following section summarizes areas and parcels within Areas 1, 4, 9 and 10, the existing easements, and what easements will be needed.

Table 5.1 - NER Plan Real Estate, Area 1

Note: Access to both sides of the project will be from the levee systems on both sides of the river. Appropriate notice will be given to landowners along the levees prior to any construction.

Landowner	Restoration Features	Landowner	Restoration Features
Joyce Lucas/Bob Lucas	Channel capacity Excavation Side pool excavation Brush fences Anchored logs or trees Supply channels for side	Bureau of Land Management	Sediment trap
Sewell Partners	Brush fences Anchored logs or trees	Porter Estates	Access to area

Table 5.2 - NER Plan Real Estate, Area 4

Note: Access to both sides of the project will be from the levee systems on both sides of the river. Appropriate notice will be given to landowners along the levees prior to any construction.

Landowner	Restoration Features	Landowner	Restoration Features
Tozzi	Eco-fences Sediment trap	Circle L Partners	Eco-fences Supply channel Anchored logs or trees Channel capacity excavation
Cheramy	Eco-fences Sediment trap	Ford-North	Sediment trap
Malinski "A"	Sediment trap Supply channel	Neilson Ranch-North	Spur dike Sediment trap Pool
Malinski "C"	Eco-fences Sediment trap Supply channel Side pool Anchored logs or trees	Ford-South	Sediment trap Pool Supply channel Anchored logs or trees Eco-fences
Canyon Oaks	Eco-fences Sediment trap Supply channel Side pool Anchored logs or trees Channel capacity excavation	Neilson Ranch-South	Eco-fences Supply channel Anchored logs or trees Channel capacity excavation Pool
Lammers	Eco-fences Supply channel Anchored logs or trees Channel capacity excavation	Roliz	Eco-fences Supply channel Anchored logs or trees Channel capacity excavation Pool

Table 5.3 - NER Plan Real Estate, Area 9

Note: Access to both sides of the project will be from the levee systems on both sides of the river. Appropriate notice will be given to landowners along the levees prior to any construction.

Landowner	Restoration Features	Landowner	Restoration Features
Bureau of Land Management	Eco-fences Anchored logs or trees Rock grade control Channel capacity excavation Pool supply channels Anchored logs or trees	Jacobson	Channel capacity excavation
River Springs Partners	Channel capacity excavation Spur dikes	Thieme	Channel capacity excavation
Wyoming Department of Transportation	Channel capacity excavation	Rino	Channel capacity excavation
Kindred	Channel capacity excavation	T.S.R. Limited	Channel capacity excavation Anchored logs or trees
Zachritz	Channel capacity excavation	Bresden	Pool Anchored logs or trees Channel capacity excavation
Teton County	Channel capacity excavation		

Table 5.4 - NER Plan Real Estate, Area 10

Note: Access would be covered under existing easements unless reconfiguration of the channel network requires access from the northwest corner of the project area.

Landowner	Restoration Features	Landowner	Restoration Features
Core Partners	Sediment trap Spur dike	W.G.V.B.	Sediment trap Anchored logs or trees Channel capacity excavation
Hoke	Anchored logs or trees	Berney	Anchored logs or trees
John Dodge Homeowners (#51)	Eco-fences Anchored logs or trees	Bear Island Partners	Anchored logs or trees
Cohen	Pool	Ackerman	Spur dike Eco-fences Anchored logs or trees Sediment trap
Mead	Spur dikes Sediment trap	Bird	Eco-fences Sediment trap
Cook	Sediment trap Pool Eco-fences Anchored logs or trees	Wolfensohn	Sediment trap
Bureau of Land Management	Pool Anchored logs or trees Eco-fences		

5.4.3 Summary of Real Estate Costs

The sponsor will use a non-standard channel improvement easement for ecosystem restoration, where a levee easement does not already exist or is insufficient, to obtain access and the right to install restoration features. (The sponsor will not use condemnation to obtain any easement or access). The restoration features proposed will likely benefit the properties involved. Therefore, compensation normally awarded to offset any adverse effect of a proposed activity usually requiring an easement (*i.e.*, utilities), is insignificant in this case.

Real estate costs for Areas 1, 4, 9, and 10 are summarized in Table 5.5 below. Detailed cost breakdowns are provided in Appendix F, Real Estate. For planning purposes it is estimated that easement acquisition will occur at a nominal cost of $1,000 per easement for not more than 34 parcels. All costs are in 1999 dollars. Real estate costs for Areas A-H are expected to be similar and are included in the Progressive Plan cost estimates.

Table 5.5 - NER Plan Real Estate Costs

Study Area	Land	Administration (Sponsor)	Administration (Government)	Total
Area 1 (Phase D)	$2,400	$12,000	$3,600	$18,000
Area 4 (Phase C)	14,400	71,200	14,400	100,000
Area 9 (Phase B)	9,600	47,600	10,800	68,000
Area 10 (Phase A)	14,400	71,000	15,600	101,000
Total initially proposed NER Plan Real Estate Costs (Areas 1, 4, 9, and 10)				$287,000
Total Progressive NER Plan Real Estate Costs (Areas A-H)				793,000
Grand Total Progressive NER Plan Real Estate Costs (Areas 1, 4, 9, 10 and A-H)				$1,081,000

5.5 Transportation

Impacts upon transportation would occur as a result of construction of the environmental restoration project and subsequent performance of work to maintain the structures. Both construction and maintenance will require similar measures to implement. However, maintenance will likely involve less effort than actual construction; therefore, potential impacts from maintenance should be less than those of construction activities.

The transport of construction materials and supplies to the project areas will increase truck traffic on primary highway routes and secondary roads. Trip repetitions for this type of traffic will generally be limited; therefore, any impact upon traffic patterns from this particular truck activity is expected to be minimal.

The ingress and egress of gravel trucks between gravel screening sites and upland disposal areas at existing gravel processing facilities will likely generate the greatest traffic increase on primary and secondary roads. Because the quantity of gravel that may be transported will reasonably vary from site to site and from year to year, establishment of an estimate for the number of repetitions necessary to perform construction and maintenance is difficult. It is reasonable to expect peaks in truck traffic that will add to or create traffic congestion.

Conflicts may exist between contractors performing maintenance of the Jackson Hole Flood Control Project and contractors constructing the environmental restoration project. The Corps will address such conflicts that occur on the Jackson Hole Flood Control Project access roads and levees. The local sponsor will identify any transportation conflicts on public roads and implement traffic control measures (such as flaggers or signage) at locations that experience more than minimal increases in traffic congestion. Operation of loaded trucks on the Jackson Hole Flood Control Project levees and access roads during construction and maintenance will likely cause impacts to the surface of these structures. The Corps will ensure repair of such surface impacts resulting from construction. The local sponsor will be responsible for repairs to the surface resulting from their post-construction maintenance activities. Because surface repairs will be implemented, impacts upon the access roads and levees would be temporary.

Staging areas for fuel and lubricant storage and dispensing will be located outside of the leveed sections of the Snake River. Staging outside the levees will dramatically decrease the potential

for unintentional releases of toxic materials into the Snake River. A minimum of one staging area will be necessary at each of the three working areas. Staging areas will be selected and any easements, licenses, or permits necessary for staging areas will be acquired by the local sponsor. The contractor and any subcontractors will be required to submit for approval, prior to initiation of construction, a hazardous materials spill and cleanup plan including tools and materials that will be on hand and readily available to facilitate containment and cleanup. All overnight equipment storage, as well as refueling and maintenance activities, will be restricted to staging areas. Based upon the above measures, no more than minimal, short-term impacts upon transportation are expected from either maintenance or construction of the environmental restoration project.

Access to work areas will occur primarily upon the roadways identified below, in addition to other unnamed roadways. Access will generally originate from public roadways and may use roadways already under easement for access to the levees for the purpose of performing O&M activities. Real estate instruments necessary for access will be identified in the local sponsor's real estate report. The local sponsor will coordinate acquisition of necessary real estate instruments.

The roads for the levee access easements are typically dirt roads and are suitable for moving construction equipment. Flows in the Snake River are too high to allow for construction access from only one side of the river so access from both sides of the river will be necessary. The contractor will coordinate with the Corps' biologist, a representative for the flood control project, and the landowner (in the field) to determine the optimum access routes for minimizing disturbances. The east and west access points for Areas 1, 4, 9 and 10 is described below. Access to areas A through H will be determined in the PED phase.

5.5.1 Area 1 Access

The west portion of Area 1 will be accessed from Fall Creek Road and involves two different access points. The first access point is for the downstream work area. The access originates off of Fall Creek Road and follows a dirt road to Sewell Levee, continuing along Sewell Levee to the work area. The access to the upstream work area originates from Fall Creek Road and follows a dirt road to the work area. This access will need to be determined in the field.

The east portion of Area 1 would be accessed from the north from South Park Loop along a 1-mile stretch of gravel road to the Lower Imenson Levee. Once on the levee, construction equipment will follow the levee until it terminates. After the levee ends, access will continue through existing shrubs and trees and over gravel bars. The contractor will coordinate with the Corps in the field to determine the optimum routes for minimizing disturbances.

5.5.2 Area 4 Access

The east portion of Area 4 will be accessed from the Federal Levee Extension. Construction equipment will leave the public highway, approximately 4 miles to the north and follow the left bank of the Federal Levee Extension to the work area. Access to the west portion of Area 4 will be from Fall Creek Road along an existing gravel road. This access crosses an existing bridge and terminates at the channel bottom. The contractor may need to navigate across gravel bars and around existing vegetation.

5.5.3 Area 9 Access

Access to the east portion of Area 9 will be from State Highway 22, which provides access to the Left Bank Federal Levee. From the Left Bank Federal Levee, an access point to the specific work areas will be selected in the field. Access for the west portion of Area 9 will originate from State Highway 390. From State Highway 390, the contractors will follow an existing dirt road to the Right Bank Federal Levee.

5.5.4 Area 10 Access

The work on the east portion of Area 10 will be reached from the downstream direction or the upstream direction. From the downstream direction, equipment will travel from State Highway 22 and then up the Left Bank Federal Levee for approximately 3 miles to the work areas. From the upstream direction, equipment will travel from Cattleman's Bridge, which is approximately 2 miles away, to the Hanson Levee. The spur dikes located to the north will be accessed from Spring Gulch Road, which is about 2 miles away. Most of the work in Area 10 lies to the west of the river and will be accessed via the Right Bank Federal Levee. From the levee, construction equipment will traverse existing gravel bars and around or through vegetated areas to the specific

work areas. Equipment could reach the levee from both the upstream and downstream directions. The downstream end of the levee will be accessed from a dirt road that runs for about three-fourths of a mile from State Highway 390 to the Right Bank Federal Levee.

5.6 Socioeconomics

The NER Plan is expected to yield the most benefit to the riparian and aquatic habitat. When the Progressive Plan alternatives are implemented the Corps speculates that over the 50-year project period it will help maintain the average annual fish numbers (cutthroat trout and other species) at their present population. Without the environmental restoration project, aquatic and riparian habitat will be expected to decline over the next 50 years. The environmental restoration project, by improving the aquatic and riparian habitat, is also expected to enhance the aesthetics of the area to visiting sports persons and tourists, in general, regardless of their objectives in visiting the Jackson Hole area. By increasing the amount of vegetation in some areas, people may have a better experience when they go fishing. Most fishermen probably would rather see trees and other vegetation than bare cobble and gravel.

Based on statistics furnished by Jackson Hole Economic Development Council Web site, local jobs maintained by the $143,000,000 output related to sports fishing, accounts for about 25 percent of the total employment of Teton County. If this output and associated sales are maintained, 4,500 jobs will be enhanced in the area.

5.7 Recreation

The Snake River in the vicinity of the NER project principally experiences recreational use from rafting and fishing, with some waterfowl hunting. Existing levees are used for a variety of recreational purposes including walking, hiking, jogging, bicycling, cross-country skiing, horseback riding, bird watching, nature viewing, picnicking, and other similar uses. The levees also provide access for direct river use such as fishing and waterfowl hunting. The NER Plan has the potential for both short-term and long-term impacts upon recreational uses. Recreational use could potentially be affected by construction, impacts from the presence of completed structures, and impacts from structure maintenance.

The effects of construction activity will occur principally in the form of short-term impacts. These impacts will occur during ingress and egress of equipment to the work sites and during actual on-site construction. Access to the work sites will occur over a variety of routes and for a variety of purposes. Access will be necessary to transport equipment, materials, and supplies to and from the work sites. Some routes will require use of levees and others will not. Of the levees that will be used for ingress and egress, some receive recreational use and others do not. Those that receive recreational use have the potential for user conflicts to develop.

At Area 9, the public has access to both the Right and Left Bank Federal Levees. Since these are proposed for construction access, a short-term impact is expected. In addition, access to reach the Left Bank Federal Levee on the east side will be through an existing conservation park used by recreationists, and access to the Right Bank Federal Levee will occur upon an existing unpaved road leading to a boat launch and parking area

The majority of recreation use in the project areas occurs near the Highway 22 Bridge in Areas D, 9, E, and 10, which witnesses year-round activity. Levees at Area D, 9, E, and 10 will be used in support of construction and will be clearly signed at all access points to alert users to the presence of trucks and other equipment. Because the greatest use by recreationists occurs on the Left and Right Bank Federal Levees upstream of the Jackson-Wilson Bridge at Areas D, 9, E, and 10, the greatest inconvenience upon recreationists will likely occur at these locations. A flagger would be posted, when necessary, at the Area 9 boat ramp to coordinate use between recreationists and construction equipment using the site for ingress and egress to construction areas.

Operation of equipment upon levees accessible to the public will create a conflict for persons hiking or walking the levee. As indicated above, traffic control measures, such as flaggers or signage, will be used at locations that will experience more than minimal conflicts between recreationists and construction-related activity. Such situations will be identified and resolution measures implemented by the local sponsor. Impacts from construction-related activity upon levee users will be temporary and will be minimized through the use of measures referenced above.

Gravel removal to maintain channel capacity and construct channel stabilization pools will occur in areas of the primary river channel. In-channel work may also involve construction of temporary water diversions or berms to reroute flows and de-water gravel removal sites. Spur

dikes will be constructed adjacent to levees where the high-velocity flows of the primary channel occur. Rafters and float fishermen will be the primary recreationists likely to be affected by the in-channel work. Fishermen fishing from the bank or wading will be less affected. The primary effect upon rafters and float fishermen will occur from the temporary alteration of the primary channel flow. The proposed gravel removal will have only a minor effect upon rafters and float fishermen.

Presence of completed eco-fences, channel stabilization pools, anchored root wad logs, and spur dikes will change the configuration of the river channel and effect flow patterns. Eco-fences, anchored root wad logs, and spur dikes will result in more permanent changes to the channel than will the channel stabilization pools. Channel stabilization pools will trap bedload materials, therefore becoming less prominent over time. However, maintenance of the channel stabilization pools after they have filled with bedload material would result in renewed changes in configuration and flows.

Permanent changes in the channel are expected to have long-term, yet minimal impacts upon rafters and float fishermen. Rafters will have to become accustomed to the new configuration and flows resulting from spur dikes, anchored root wad logs, and eco-fences. Because these structures will not be in the middle of the primary flow, rafters and float fishermen should have little difficulty negotiating or bypassing the structures. The effort required for rafters and float fishermen to learn the new changes are expected to be no greater than is required each year after seasonal high flows. The permanent changes in configuration and flow will not de-water the channel or restrict access. The permanent changes have considerable potential to provide long-term benefits to recreational users through the creation of additional fish habitat.

If structures are damaged by high flows, parts of structures, such as cables from eco-fences, could pose a hazard to rafters and float fishermen. To alert river users to the presence of the new structures, the local sponsor will implement a public information campaign and perform monitoring and maintenance to identify potentially unsafe structure conditions.
Gravel removal to maintain channel capacity and construct channel stabilization pools is expected to have even less impact on recreationists than the eco-fences, channel stabilization pools, anchored root wad logs, and spur dikes. Channel stabilization pools will cause slower flows, creating a pool effect, therefore not posing a hazard or barrier to floaters. This change is not expected to have more than a minimal effect on rafters and float fishermen. Floaters and rafters will likely experience improved floating conditions due to stabilization of the channel.

Overall, the permanent, long-term effects upon recreation resulting from the presence of the completed structures are expected to be minor.

The effects of maintenance upon recreation activities will be similar to those resulting from construction. However, work required to perform maintenance is reasonably expected to be less than would be required to actually construct the environmental restoration project. Primary effects will result from ingress and egress of equipment and actual construction activity and will be short-term.

A public information campaign will be implemented by the local sponsor to inform the recreating public about the environmental restoration project and possible conflicts between recreationists and construction activities. The campaign will include installation of appropriate signage at all levee access points and at the ramp and conservation park at Area 9. An information brochure will be prepared and distributed by the local sponsor to all fishing and rafting outfitters as well as placed at information boards at public access areas. Other sources available to the local sponsor for distributing information to the public may include the print media and radio. The campaign will be implemented both prior to and during construction.

5.8 Aesthetics

The Jackson Hole area is popular as a year-around recreation destination. The area's spectacular scenery is of national significance, as evidenced by the establishment of the Grand Teton National Park in 1929. The proposed environmental restoration project areas are located in the outwash plain of the Snake River. The river channel is relatively wide and braided with extensive areas of gravel bars. Riparian vegetation is found along many of the channels. Stands of trees, composed primarily of cottonwoods, willow, and alder are scattered throughout the outwash plain. Views of the floodplain, by boaters and other recreationists using the Snake River, are generally restricted because of adjacent riverbanks, levees, and vegetation. The primary views along the rivers are of the mountains, particularly the Grand Teton Mountains, which can be viewed beyond the riverbanks and levees in locations where there are openings in the riparian vegetation.

Since the mid-1990's, Area 1 has undergone extensive lateral erosion due to the "firehose" effect of concentrated river flows emerging from the confined channel upstream. The installation of

eco-fences and anchored root wads will help to reestablish island vegetation as well as help to reestablish island vegetation as well as help protect existing islands and encourage growth of new islands.

The vegetation at Area 4 is predominately shrub-willow. Most of the existing islands currently within the channel are devoid of vegetation due to island instability and changing river flows. The installation of eco-fences and anchored root wad logs will help reestablish island vegetation.

The river at Area 9 is somewhat restricted and the islands are devoid of vegetation. The vegetation along the shoreline is predominantly shrub-willow. Rock grade control structures will be constructed flush with the existing channel bottom and will help prevent bank erosion and degradation of existing habitat. Eco-fences and anchored root wad logs will assist in revegetation of existing islands and establishment of new islands. Spur dikes will be used to provide bank protection and enhance fisheries habitat by creating flow diversity and enhancing pools, fish resting areas and riffles, thus improving the visual quality of the riverbanks.

Area 10 is located at the confluence of the Gros Ventre and Snake Rivers. This area has extensive cottonwood vegetation on existing islands and along the shoreline. Eco-fences and anchored root wad logs will assist in promoting a more diverse vegetative cover along existing shorelines and encourage the growth of new islands. Spur dikes will enhance fish habitat and provide additional bank protection. This will allow regeneration of native plants as well as improve the visual quality of the riverbanks.

The removal of gravel to maintain channel capacity and construct channel stabilization pools and the presence of the anchored root wad logs, eco-fences, off-channel pools, and secondary channels are not expected to contrast sharply with the existing surroundings. The proposed measures are expected to create long-term potential for restoring aquatic and terrestrial habitat along the environmental restoration project area. Over time, with the reestablishment of islands and vegetation, the aesthetics of the project area would improve.

During construction stockpiled gravel, screened cobble, and discharged riprap for eco-fences, spur dikes, and rock grade control will contrast with the surroundings however, stockpiling of gravel and screened cobble may not occur. If it does, visual impacts would be temporary because the material will only be in place a short period of time. Accumulation of woody debris on the piling and rock eco-fences will cause their visual contrast to be short-term. Rock grade

control will be unobtrusive due to the embeddedness of the material. Contrast of the spur dikes to existing surroundings will be evident to rafters and float fishermen traveling the river and to persons visiting areas that are publicly accessible. Anchored root wad logs will blend in with the setting.

5.9 Cultural Resources

A copy of the Corps' Survey Report was forwarded to the Wyoming Division of Cultural Resources, State Historic Preservation Office, for review and concurrence. In their letter of February 12, 1997, the SHPO responded that no sites meeting the criteria of eligibility for the National Register of Historic Places will be affected by the environmental restoration project. The SHPO recommended the project proceed in accordance with state and Federal laws, subject to the following stipulation: "If any cultural materials are discovered during construction, work in the area should halt immediately and the Corps and SHPO staff must be contacted. Work in the area may not resume until the materials have been evaluated and adequate measures for their protection have been taken." Refer to Appendix H, Environmental Assessment, which contains Appendix D for the SHPO letter concurring with the Corps' determination of "no effect" for areas 1, 4, 9 and 10. Additional coordination may be needed for areas A-H which will be conducted during the PED phase.

5.10 Cumulative Effects

The Flood Control Act of 1950 authorized flood protection by levees and revetment along the Snake River in the Jackson Hole, Wyoming area. The project was completed in the fall of 1964. Levees have been added to the system by other agencies and by emergency flood fight operations of the Corps and Teton County through 1997. The effect of these measures has been the alteration of the physical character of the river, both inside and outside of the levees, along approximately 25 miles between Moose Bridge and South Park National Elk Feedgrounds. Presently, the following effects have been observed:

- The width of the Snake River floodplain is reduced by the levees.
- Flow velocities through the leveed sections are increased.
- Elevated quantities of bedload material is transported through the area.

- Islands and associated vegetation is eroding.
- Water flows to spring creeks outside of the levees have been reduced.
- Spawning habitat for cutthroat trout has been reduced or destroyed.
- The composition and quality of riparian vegetation outside of the levees is changing.

The environmental restoration measures being proposed under the Jackson Hole, Wyoming, Environmental Restoration Project, will have both short- and long-term effects on the Snake River.

Environmental restoration measures proposed for Area 1 include excavation of a single channel stabilization pool and four off-channel pools with connecting upstream and downstream secondary channels, construction of eco-fences, and placement of anchored root wad logs. Construction will result in minor, nonbeneficial short-term impacts to water quality, air quality, aesthetics, recreation, aquatic and terrestrial species and habitat, and local transportation. Presence of the completed structures will have long-term beneficial effects upon water quality, recreation, and aquatic and terrestrial species and habitat.

Environmental restoration measures in Area 4 will include: excavation of two channel stabilization pools and three off-channel pools with connecting upstream and downstream secondary channels; construction of eco-fences and spur dikes; placement of anchored root wad logs; and removal of gravel to maintain channel flow capacity within 100-year event flows. Construction will result in minor, nonbeneficial short-term impacts to water quality, air quality, aesthetics, recreation, aquatic and terrestrial species and habitat, and local transportation. The completed structures will cause long-term beneficial effects upon water quality, recreation, and aquatic and terrestrial species and habitat by stabilizing the channel and allowing recovery of aquatic and terrestrial habitat. Actions proposed in Area 4 will not add to the cumulative adverse effects caused by previous flood control actions at Area 4.

Environmental restoration measures in Area 9 will include: construction of eco-fences, spur dikes, placement of anchored root wad logs, and removal of gravel to maintain channel flow capacity within 100-year event flows. Construction will result in minor, nonbeneficial short-term impacts to water quality, air quality, aesthetics, recreation, aquatic and terrestrial species and habitat, and local transportation. Presence of the completed structures in Area 9 will result in long-term beneficial effects upon water quality, recreation, and aquatic and terrestrial species and habitat. The changes attributable to the collective effect of actions proposed for Area 9 will

decrease nonbeneficial effects of past flood control activities and cause an overall net increase in beneficial effects in the long-term. No measurable increases in the net detrimental effects caused by previous flood control activities will occur.

Environmental restoration measures in Area 10 will involve excavation of a single channel stabilization pool and two off-channel pools with connecting upstream and downstream secondary channels, construction of eco-fences, placement of anchored root wad logs, spur dikes, and removal of gravel to maintain channel flow capacity within 100-year event flows. Construction in Area 10 will also cause minor, nonbeneficial short-term impacts to water quality, air quality, aesthetics, recreation, aquatic and terrestrial species and habitat, and local transportation. Water quality, recreation and aquatic and terrestrial habitat will benefit in the long-term from the presence of the completed structures. Changes caused by the cumulative effect of actions proposed for Area 10 will cause the nonbeneficial effects from past flood control activities to diminish. In the long-term, an overall net beneficial increase in aquatic and terrestrial habitat will occur.

Environmental restoration measures in Areas A through H will have similar effects as those anticipated for Areas 1, 4, 9, and 10. The cumulative effect for restoration of the entire 22-mile reach of the Snake River from Teton National Park to the South Park Elk Feedgrounds is significantly greater than result of restoring one or more of the individual areas identified in this Study.

The cumulative effect of past and proposed actions along the Snake River will not cause additional reduction in the width of the floodplain, increase flow velocities through the levied areas, increase transport of bedload material, destabilize the channel, erode islands and vegetation between the levees, or diminished flows to spring creeks outside of the levees. The cumulative effect of the proposed environmental restoration project will be improved water quality through reduced velocities and stabilization of the channel, reduced erosion of islands and loss of vegetation, opportunity for the reestablishment of islands and vegetation, and creation of additional habitat for cutthroat trout and other aquatic and terrestrial species.

5.11 Project Performance

The paragraphs below describe the expected performance and effectiveness of each project element within the restoration areas, and the impacts to areas downstream of the proposed projects.

5.11.1 Eco - Fence

Fence structures of various designs have been tested for use as bank protection or river training structures. A number of these designs and case histories are described in the December 1981 U.S. Army Corps of Engineers Publication, *Final Report to Congress: The Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, PL 93-251.* In some cases, particularly in meandering streams where the flow velocities were low, they have proved effective in collecting sediment and stabilizing the channel. The effectiveness of fences in braided channels with high-velocity flow is much less certain.

The effectiveness of the fences will depend, to a large degree, on the amount of floating debris available in the river and actually trapped against the fences. In order to be effective, the fences must trap enough debris to uniformly block most of the flow along the length of the fence. If too little accumulates, the current may pass through the fence with little or no velocity attenuation. An upstream fence may trap most of the available debris, reducing the supply to downstream fences. Depending on the angle of attack, floating debris may be deflected and fail to become trapped against the fences. There is also a risk that excessive flow may escape under floating debris, or erode a path under the fence below the lowest cross-cables.

Failure of some fence projects in other locations has resulted from insufficient depth of supporting posts, breakage, or an alignment that allowed the flow to bypass or flow behind the fence. At impingement points, velocities of 12 fps (or even higher) have been measured during peak flows. The end of the fence extending out into the channel will be exposed to the greatest stress. There will be erosion around the toe, force fluctuations resulting from debris striking the fence or shifting position, and vibration caused by vortex shedding. In the most severe case, erosion may extend to a depth of up to 15 feet below the water surface. Debris may not collect effectively at the end of the fence leaving the fence exposed at this location. Since undercutting

is likely to be the worst at the end of the fence, experience may dictate the need to extend cross-cables and wire mesh to a greater depth at this location.

The need for a minimal level of maintenance cannot be overemphasized. The visual impact of the fences could become a major consideration. The fences will create a scalloped pattern of vegetation and debris, with the tips of the fences forming the points. Insufficient debris may leave the tip of the fence or other portions of the structure exposed. With no maintenance, a failed fence could become an eyesore and a possible hazard with partially-buried woody debris mixed with a tangle of steel posts and cables strung out downstream of the original construction site.

The number and extent of river training structures is not sufficient to assure that the river cannot escape and follow an undesirable alignment. The river will change course frequently and may, for a time, completely abandon the spur dikes, fences, and other restoration features.

5.11.2 Secondary Channels

It should be assumed that most of the small secondary channels leading to off-channel pools will be blocked by gravel at their upper ends after each runoff season. Although groundwater seepage will provide some flow, it should be assumed that most of channels will have to be re-opened each season in order to provide an optimum exchange of water for the downstream pools. Starting at the edge of the main channel, a small connecting channel will be extended downstream or the existing channel will be deepened until a flow of 2 to 3 cfs was developed in the channel leading to the pool.

In some areas sufficient flow may be developed from groundwater seepage without actually having to connect the channel to the main river. The channel-excavation would typically be around 4 feet wide at the bottom, 200 feet long, and 3 feet deep. A backhoe would typically be used to excavate the channels. Where possible, particularly in vegetated areas, it will be desirable to remove the excavated gravel. However, in may cases the amount of material will be small or the location inaccessible, and less disturbance will be involved if material were side-cast and graded to blend with the surrounding terrain.

The secondary, supply channels will have little effect on the overall hydraulics of the system. Hydraulically, these channels will be successful if they survive through successive high-flow periods without excessive maintenance. However, the channels will not be useful if the substrate and flow-regime does not contribute to improved habitat.

5.11.3 Channel Stabilization Pools

Since the supply of sediment being transported downstream is not precisely known and may vary by at least an order of magnitude between years, the optimum size and effectiveness of the sediment traps is not known. Gravel removal will need to be closely controlled and its effects monitored. Removal of more gravel than is being re-supplied will result in progressive lowering of the channel bed within the designated sediment trap boundaries, excessive headcutting upstream, and excessive channel entrenchment downstream. This could lead to a local depression of the water table, and undercutting of the toe of the riprap on nearby levees.

During the coldest winter months of November-February, the potential for ice blockage of the active, low-flow channel will be increased in vicinity of the gravel trapping areas. The low-flow channel may be frozen clear across at times with part of the flow passing under the ice cover and the remaining flow backing up and overflowing into secondary channels that would normally be dry at this time of the year. Since the distance between the levees is several times the width of the low-flow channel, and there is no development immediately adjacent to the low-flow channel in other areas, this condition is not expected to create any increased risk of flooding or other serious problems.

5.11.4 Off-Channel Pools

Depending on the location and the timing of high flows, pools could be refilled with gravel and cobbles and totally eliminated before they have existed long enough to perform a useful role. In the worst case, some of the pools may be eliminated by the next high flow after construction. Pools in most areas will be subject to refilling during high-flow seasons. If this process occurs over a period of time it can actually be beneficial, since it will provide a controlled sequence of differing plant communities and provide more diverse habitat. In some locations the pools may serve a dual role as habitat providers and sediment traps. Those located some distance from the

main channel will likely last a number of years. They will gradually refill with silt and sand brought in by the interconnecting channels, and by general overbank flow during high-flow periods. Due to the braided nature of the river, it is nearly impossible to select locations where pools will be subjected to a predictable level of protection from flood events. An additional potential problem is isolation of the pool and entrapment of fish during low-flow periods due to excessive seepage into the gravel bed or banks of the pool. Freezing of the pools and secondary channels during the winter may also be a consideration.

5.11.5 Spur Dikes

Spur dikes will occasionally be damaged by high flows. Measurements at various locations on the existing channel indicate that erosion can extend down to at least 15 feet below the high-water level. It would not be practical to construct the dikes with large enough stone and with a deep enough toe to avoid any possibility of damage. The mode of damage will likely be undercutting of the toe of the dike and collapse of material into the void with some material being transported downstream. Repair will involve adding enough riprap to restore the original geometry.

5.11.6 Effects of Alternatives on Existing Hydraulic Conditions

At Area 1, the NER Plan includes channel excavation, eco-fences, sediment traps, spur dikes, side pools, anchored woody debris, supply channels, and a modest shortening of the channel. No rises in the 100-year water surface are expected as a result of the restoration measures. The model shows lower water-surface elevations up to about 1 ft in the excavated areas. Localized rises upstream of the channel restoration work are results of extrapolation inaccuracies. Fence structures are to be located in previously vegetated areas. The gravel removal and channel shortening should shift the river regime slightly toward channel entrenchment, increasing channel stability and reducing the risk of flooding and erosion.

At Area 4, the NER Plan includes channel excavation, eco-fences, sediment traps, spur dikes, side pools, anchored woody debris, and supply channels. As documented in Appendix B, Hydrology, the 100-year water-surface elevations are lowered as a result of the project (Plate 34). Average channel velocities for all events (10-, 50-, 100-, and 500-year and 1997 historical

flood) are generally higher in the restored condition and reflect increased efficiency due to the channelization components.

At Area 9, the NER Plan includes channel excavation, eco-fences, side pools, staggered log protection, anchored woody debris, spur dikes, grade control, and supply channels. The 100-year water with-project surface elevations are generally less than or equal to the existing water-surface elevations throughout the restoration area (Plate 35). (Note: The rise in water-surface elevation shown at cross section 13 on Plate 35 is due to a mathematical anomaly in the profile and not to any physical change in the river.) The with-project average channel velocities are considerably lower in the downstream portion of the area, but are equal to or higher than the existing velocities in the upper section.

At Area 10, the NER Plan includes channel excavation, eco-fences, sediment traps, side pools, spur dikes, anchored woody debris, and supply channels. The 100-year water with-project surface elevations are generally lower in the downstream portion of restoration area, but are somewhat higher (on the order of 1 foot) in the upstream portion (Plate 36). However throughout the entire site, the with-project profile is lower than the 1973 Flood Insurance Study profile. The with-project average channel velocities were somewhat lower (but almost equal) in the downstream portion of the area but were generally higher in the upstream portion.

Area A through H effects will be determined during the PED phase. The features will be designed to the same standards as Areas 1, 4, 9, and 10. The project flood profile will be lower than the 1973 *Flood Insurance Study* profile.

5.11.7 Downstream Impacts

Downstream impacts from the proposed restoration projects are minimal. In terms of flood control, the proposed changes to the low-flow channels and installation of sediment traps only affect the project area and do not affect downstream water-surface elevations or velocities (see Tables 7 through 9 and 11 through 13 in Appendix B, Hydrology). In terms of levee maintenance, the restoration alternatives will tend to guide low flows away from the banks and levees and toward the center of the river, and will reduce impingement on the levees and the associated erosion in the immediate downstream vicinity of the project. However, given high bedload of the system and the random nature of the low-flow channel morphology between the

levees, the river training effects of the restoration measures will not carry forward downstream of the project areas for any appreciable distance.

The development of all areas identified in the Progressive Plan will have a stabilizing effect on the entire reach from Teton National Park to the South Park Elk Feedgrounds. The Progressive Plan is expected to provide restoration to important natural resources and reduce flood control maintenance requirements.

5.12 Coordination with other Regional Restoration Initiatives

The focus of this project will extend beyond its physical improvements. The community, local interest groups, and property owners have indicated their support for this project and their desire to create additional restoration opportunities. Currently local interests are considering a Section 1135 project to restore flows behind or landward of the levees for restoration of spawning habitats. The intent of the flood control project modification study (Section 1135) will be to restore spring creek and wetland values. The Teton County Conservation District, along with the WGFD, Trout Unlimited and the National Fish and Wildlife Foundation, are expending additional efforts in restoring riparian and spring creek habitats behind the levees. This study and the resulting construction will further stimulate local, regional, and natural restoration interests. The overall goal of the supporting interests of this project is to create a long-term cultural shift toward the natural management of these important sustainable resources.

6. PLAN IMPLEMENTATION

This chapter summarizes cost-sharing requirements and procedures necessary to implement the environmental restoration features of the proposed NER Plan.

6.1 NER Plan

The identified NER Plan provides the maximum National Ecosystem Restoration (NER) benefits. Because of its positive contributions to improving the environmental values within the Jackson Hole study area, Alternative A3+B3+C3+D3 (50-year piling eco-fence designs and other features as described in Section 5 at Areas 1, 4, 9, 10 and A through H) is recommended for implementation.

6.2 Division of Responsibilities for Implementing Recommended Plan

The WRDA 86 and various administrative policies have established the basis for the division of Federal and non-Federal responsibilities in the construction, maintenance, and operation of Federal water resource projects accomplished under direction of the Corps. Anticipated Federal and non-Federal responsibilities are described in this section. The final division of specific responsibilities will be formalized in the project cooperation agreement.

6.2.1 Federal Responsibilities

The estimated Federal share of the total first cost of the project is 65 percent of first costs (first costs are all costs to implement project less LERRD and O&M costs). The Federal government responsibilities are anticipated to be:

a. Design and prepare detailed plans and specifications.

b. Administer contracts for construction and supervision of the project after authorization, funding, and receipt of non-Federal assurances.

c. Conduct all necessary cultural resource investigations and coordinate and implement any necessary preservation or mitigation measures.

d. Conduct periodic inspections with the non-Federal sponsor to determine adherence to the post-construction maintenance requirements

6.2.2 Non-Federal Responsibilities

Non-Federal or local responsibilities are anticipated to be:

a. Provide 35 percent of the separable project costs allocated to environmental restoration as further specified below:

1. Enter into an agreement, which provides, prior to execution of a project cooperation agreement for the project, 25 percent of design costs;
2. Provide, during construction, any additional funds needed to cover the non-Federal share of design costs.
3. Provide all lands, easements, and rights-of-way, including suitable borrow and dredged or excavated material disposal areas, and perform or assure the performance of all relocations determined by the Government to be necessary for the construction, operation, and maintenance of the project;
4. Provide or pay to the Government the cost of providing all retaining dikes, wasteweirs, bulkheads, and embankments, including all monitoring features and stilling basins, that may be required at any dredged or excavated material disposal areas required for the construction, operation, and maintenance of the project; and
5. Provide, during construction, any additional costs as necessary to make its total contribution equal to 35 percent of the separable project costs allocated to environmental restoration.

b. For so long as the project remains authorized, operate, maintain, repair, replace, and rehabilitate the completed project, or functional portion of the project, at no cost to the Government, in accordance with applicable Federal and State laws and any specific directions prescribed by the Government.

c. Give the Government a right to enter, at reasonable times and in a reasonable manner, upon land, which the local sponsor owns or controls for access to the project for the purpose of inspection, and, if necessary, for the purpose of completing, operating, maintaining, repairing, replacing, or rehabilitating the project.

d. Assume responsibility for operating, maintaining, replacing, repairing, and rehabilitating (OMRR&R) the project or completed functional portions of the project, including mitigation features without cost to the Government, in a manner compatible with the project's authorized purpose and in accordance with applicable Federal and State laws and specific directions prescribed by the Government in the OMRR&R manual and any subsequent amendments thereto.

e. Comply with Section 221 of the Flood Control Act of 1970 (PL 91-611), as amended, and Section 103 of the WRDA 86, as amended, which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until the non-Federal sponsor has entered into a written agreement to furnish its required cooperation for the project or separable element.

f. Hold and save the Government free from all damages arising for the construction, operation, maintenance, repair, replacement, and rehabilitation of the project and any project-related betterment's, except for damages due to the fault or negligence of the Government or the Government's contractors.

g. Keep and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project to the extent and in such detail as will properly reflect total project costs.

h. Perform, or cause to be performed, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 USC 9601-9675, that may exist in, on, or under lands, easements or rights-of-way necessary for the construction, operation, and maintenance of the project; except that the non-Federal sponsor shall not perform such investigations on lands, easements, or rights-of-way that the Government determines to be subject to the navigation servitude without prior specific written direction by the Government.

i. Assume complete financial responsibility for all necessary cleanup and response costs of any CERCLA regulated materials located in, on, or under lands, easements, or rights-of-way that the Government determines necessary for the construction, operation, or maintenance of the project.

j. To the maximum extent practicable, operate, maintain, repair, replace, and rehabilitate the project in a manner that will not cause liability to arise under CERCLA.

k. Prevent future encroachments on project lands, easements, and rights-of-way, which might interfere with the proper functioning of the project.

l. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (PL 91-646), as amended by Title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (PL 100-17), and the Uniform Regulations contained in 49 CFR part 24, in acquiring lands, easements, and rights-of-way, and performing relocations for construction, operation, and maintenance of the project, and inform all affected persons of applicable benefits, policies, and procedures in connection with said act.

m. Comply with all applicable Federal and State laws and regulations, including Section 601 of the Civil Rights Act of 1964 (PL 88-352), and Department of Defense Directive 5500.11 issued pursuant thereto, as well as Army Regulation 600-7, Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army.

n. Provide 35 percent of that portion of total cultural resource preservation mitigation and data recovery costs attributable to environmental restoration that are in excess of 1 percent of the total amount authorized to be appropriated for environmental restoration.

o. Not use Federal funds to meet the non-Federal sponsor's share of total project costs unless the Federal granting agency verifies in writing that the expenditure of such funds is authorized.

6.3 Preconstruction Engineering and Design Phase

The PED phase will follow the feasibility study. The purpose of this phase is to complete all of the detailed, technical studies and design needed to begin construction of the Jackson Hole Environmental Restoration Project. This phase ends with the completion of the first detailed construction drawings and specifications (often called plans and specs, or P&S).

Preconstruction engineering and design will be cost shared between the Corps and the sponsor in the same proportions as the project's construction cost (65 percent Federal and 35 percent non-Federal). The major documents prepared during this phase will be the design memorandum (DM), which will include the results of advanced technical engineering studies and design; the plans and specifications, which are the detailed drawings and instructions for building the project; and the project cooperation agreement (PCA), which describes the sponsor and Corps responsibilities for project construction, operation and maintenance.

Key events during the PED phase will include:

- Begin the PED phase when the Walla Walla District receives funds.
- Update Real Estate Plan (REP).
- Design memorandum approved (DM).
- Plans and specifications approved (P&S).
- Project cooperation agreement (PCA) prepared.

6.4 Construction Phase

The construction phase will begin after Congress appropriates funds specifically for the initiation of construction of the Jackson Hole, Wyoming, Environmental Restoration Project and these funds are allotted to the Walla Walla District. The project cooperation agreement will then be signed after Congress appropriates funds for construction. Formal notification for the sponsor to proceed with real estate acquisitions will occur after the PCA is signed.

Construction work at the project site will begin soon after the PCA is approved and executed, the real estate easements are acquired, and a construction contract is awarded.

Two major documents are also prepared during this phase: the construction contract, which is the agreement between the Corps and the contractor(s) about how the project will be built, and the project operation and maintenance (O&M) manual, which specifies the instructions for the sponsor to follow for project use after construction is finished. In addition, National Environmental Policy Review for Areas A through H will occur.

Key events during the construction phase will include:

- Appropriation of construction funds.
- PCA approval and execution.
- Construction contract advertised.
- Construction contract awarded.
- Phased construction of restoration features initiated.
- Approval of operation and maintenance manual.
- Completion of construction.
- Acceptance of project and transfer to sponsor.

6.5 Construction Phasing

The twelve recommended restoration areas constitute the entire project, and from a construction standpoint, can be considered as independent projects. If all 12 of the areas are implemented, construction will require 15 years for completion. The first area will require six years to complete, followed by the second area, requiring 5 years, the third area 4 years, and all remaining areas 3 years. Construction can be initiated at one or more site each year. Each area will be monitored for physical and environmental performance for a period of 5 years following completion of construction for the affected area. It is recommended that work begin on Area 9 first, and then proceed through Areas 1, 4, 10, and A through H. Socioeconomic and

environmental factors, as well as changes in the river channel, may modify the priorities and require a change in the order of construction.

Rock barbs and off-channel pools may be constructed at any time during the construction year, if groundwater conditions and environmental requirements are met. However, channel capacity excavation and eco-fences must perform as a completed unit during the high-flow period. In order to maintain adequate conveyance, priority will be placed on completion of the channel excavation. In no event will the eco-fences be completed prior to completion of the excavation in an adjacent channel. Channel excavation, replacement of oversize material, removal of stockpiled gravel from the active channel area and construction of eco-fences will be completed prior to the beginning of the spring runoff period. Most construction is likely to occur during the low-flow period and during moderate weather. Gravel extraction will be more difficult, fence piling will be hard to drive, and soil cannot be effectively replaced and compacted at the fence tie-off points when the ground is frozen.

6.6 Project Monitoring Phase

A post-construction assessment Monitoring Plan was developed to address three general aspects of the project: compliance, validation, and effectiveness. Monitoring will address the project objectives and determine project effectiveness. Adjustments ("fine-tuning") to the project (and operations) may be undertaken in the field to correct any deficiencies that are limiting factors for ecosystem restoration benefits. The monitoring program will be no longer than 5 years following the construction of the project at each site. The cost associated with this activity will be cost-shared with the local sponsor in accordance with the cost-sharing requirements specified for project implementation and is included in the project construction costs. The total cost of the 5-year program is estimated at $1,691,000 at October 1999 price levels.

6.7 Operation and Maintenance Phase

Following completion of the monitoring period at each site, all responsibility for ongoing project operation and maintenance including repair, rehabilitation, and major replacement will be turned over to the sponsor. The sponsor's responsibilities in this phase also include final certification of all necessary real estate and permit requirements for completion of project O&M. Detailed

O&M requirements will be specified in the project O&M manual to be developed during the PED and Construction Phases of the project. All O&M requirements in this phase are funded 100 percent by the sponsor. O&M activities for the project include maintenance of eco-fences, secondary channels, channel stabilization pools, and spur dikes. Anticipated O&M requirements are discussed in Sections 5.3.2 Project Maintenance, and 5.11 Project Performance.

6.8 O&M Efficiencies for Flood Control Projects from Environmental Project

The removal of gravel to create and stabilize channels and the construction of spur dikes and eco-fences is expected to reduce the cost of maintaining the existing flood protection project. This will be accomplished by directing flows away from levees and stabilizing the river within certain limitations, which will reduce impinging flows. Impinging flows are channel shifts that direct the flows directly against levees. When this occurs, the velocity of the flow often exceeds 12 feet per second, and may remove the protective layer of rip rap from the levee. Removing the rip rap from the levee face exposes the gravel cobble core to rapid erosion and failure.

By stabilizing channel movement throughout the restoration project impinging flows are less likely to occur. One of the tools used in environmental restoration are spur dikes. Spur dikes, as discussed in this report, extend perpendicularly or at a slight up or down angle (depending upon the specific design) deflecting the flow and reducing the energy impacting the levee. Spur dikes will be constructed in the environmental restoration project to create and enhance fisheries habitats. A secondary benefit of spur dikes is reduced levee maintenance. During the maintenance of the environmental restoration project, spur dikes requiring repair will be inspected in the field by the Corps Chief, Emergency Management Branch and the sponsor, Teton County. When it is determined that a damaged spur dike will provide levee protection, the cost of the repair will be credited to the flood control maintenance project. It is envisioned that the final location of the spur dikes will be a joint effort of the Corps, Emergency Management Branch and Teton County. Spur dikes will be located in high-energy locations where they provide levee maintenance benefits and fisheries habitat. Consequently, it is envisioned that spur dike repairs will be made as part of flood control project operation and maintenance.

6.9 Cost Allocation

Cost allocation is the practice of allocating the separable costs of a project to the project purpose that they serve. For this project, all costs have been allocated to the purpose of NER.

6.10 Cost Apportionment

Cost sharing for construction of this project will be in keeping within current Corps of Engineers policy whereby for environmental restoration projects, the non-Federal share will be 35 percent of the project implementation costs (pre-construction engineering and design, and construction). Non-Federal sponsors shall provide 100 percent of LERRDs, and OMRR&R. The value of LERRD shall be included in the non-Federal 35 percent share. Where LERRD exceeds the non-Federal sponsor's 35 percent share, the sponsor will be reimbursed for the value of LERRD that exceeds the 35 percent non-Federal share. After appropriate accounting for LERRD and required non-Federal sponsor project coordination activities under the terms of the Design Agreement and the Project Cooperation Agreement, any balance of the non-Federal share will be provided in cash during construction. Table 6.1 below provides a summary of the cost apportionment between the Federal and non-Federal interests for the initially proposed NER Plan.

Table 6.1 - Basic Cost Apportionment (FY99 Dollars)

BASIC PROJECT			
	FEDERAL (65%)	NON-FEDERAL (35%)	TOTAL
ECOSYSTEM RESTORATION	$33,957,300	$18,284,700	$52,242,000
LERRD'S VALUE	---	(1,081,000)	(1,081,000)
CASH CONTRIBUTION	33,957,300	17,203,700	$51,161,000

6.11 Completed, Current and Future Work Eligible for Credit

There is no completed work, current or planned future work that is eligible for credit under existing Corps policy. However, the non-Federal sponsor has completed during the course of the feasibility phase, advance restoration measures that are consistent with the recommended Federal plan, providing valuable information regarding the effectiveness and viability of the proposed project elements. The costs associated with the measures that have been implemented in advance by the local sponsor are not included as part of the overall project cost.

6.12 Institutional Requirements

Before an agreement is signed for Federal construction of the cost-shared project, the local sponsor will prepare the following financial analysis:

- The local sponsor's project-related yearly cash flows (both expenditures and receipts where cost recovery occurs), including provisions for major rehabilitation and operational contingencies and anticipated, but uncertain repair costs resulting from damages from natural events

- The local sponsor's current and projected ability to finance its share of the project cost and to carry out project implementation operation, maintenance, and repair/rehabilitation responsibilities.

- The means for raising additional non-Federal financial resources including but not limited to special assessment districts.

- The steps that the local sponsor will take to ensure it will be prepared to execute its project-related responsibilities at the time of project implementation.

In addition, as part of any Project Cost Sharing Agreement, the local sponsor will be required to undertake to save and hold harmless the Federal government against all claims related to environmental restoration, and other activities, associated with this project.

6.13 Environmental Requirements and Regulatory Permitting

The initially proposed NER Plan would result in the discharge of fill material into waters of the United states during the period of construction. It also may result in longer-term discharges associated with O&M activities. A Section 404(b)(1) evaluation was prepared to address Clean Water Act issues and a 401 Certificate was obtained from the Wyoming Department of Environmental Quality for Areas 1, 4, 9, and 10. Additional compliance will be conducted for Areas A through H during their respective PED phases. Applicable local or state permits are the requirement of the local sponsor.

In the Alternative Formulation Briefing held July 1999 in Portland Oregon, the sponsor and local interests expressed an interest in private individuals being able to use the tools developed in this study. The Corps (Walla Walla and Omaha Districts) will request funding to explore the development of regional permits under Section 404 of the Clean Water Act. Regional permit development efforts could begin in FY 00 during the Planning, Engineering, and Design phases of this project. The Corps hopes to develop criteria so that the tools developed in this study (channel creation; spur dikes; eco-fences; anchored woody debris; and secondary pools and channels) may be used by private individuals. Criteria (materials, designs, hydrologic functions, and biological functions) will be available for the individual use of these tools and for the combined use of various tools under specific physical and biological conditions. Public and agency input is considered in the development of regional permits.

6.14 Sponsorship Agreements

The local sponsor (Teton County) will provide a Letter of Intent acknowledging sponsorship requirements of the Jackson Hole, Wyoming, Environmental Restoration Project. The letter will be provided in May 2000 following the development of a memorandum of understanding with Teton County Conservation District. Prior to the start of construction, the local sponsor will be required to enter into a Project Cooperation Agreement (PCA) with the Federal Government that it will comply with Section 221 of the Flood Control Act of 1970 (PL 91-611), and the WRDA 86.

7. SUMMARY OF COORDINATION, PUBLIC VIEWS, AND COMMENTS

7.1 Non-Federal Views and Preferences

The non-Federal views and preferences regarding environmental restoration measures, and the problems they addressed, in general were obtained through coordination with the local sponsor and with the other various local and regional public agencies, community activists, resource conservation groups, and the general public. These coordination efforts consisted of a series of public meetings held during the reconnaissance and feasibility phases, through surveys, through the maintenance of a point-of-contact that any interest could discuss matters with, and a mailing list by which invitations to public meetings were distributed. Announcement of public meetings was made in local newspapers, giving date, time, place, and subject matter.

7.2 Views of the Non-Federal Sponsor

The sponsors, Teton County and the Teton County Conservation District have provided a strong partnership with the Corps throughout the study. Fifty percent of the overall requirements of the study (25 percent cash and 25 percent in-kind work) were contributed by the sponsor. In-kind products such as real estate were complex tasks were performed professionally, in coordination with property owners and local interests, and internally coordinated with Corps staff. The sponsor(s) have indicated their willingness to continue support during the project's implementation phase. In October 1998, the sponsor(s), with Corps over-sight and assistance embarked on a demonstration project that is representative of some of the key elements found in the Corps' initially proposed NER Plan. The demonstration project was funded by Teton County, in cooperation with Teton Conservation District, a private contractor, and the National Fish and Wildlife Foundation. The demonstration project was completed in 1 year and is being monitored. The supplementary section at the end of this study includes a report (*Final Report: Snake River Restoration Demonstration Project*, by Teton Conservation District) and an article ("The Good Flood" from the Ingersoll-Rand technical publication, *Compressed Air)*, which describe the demonstration project. This local effort accomplished three important milestones:

- It demonstrated the sponsor's interest and ability to sponsor the restoration effort.
- It demonstrated the sponsor's ability to raise money.
- It provided a model for the public and interest groups to see, and for technical entities to analyze possible with-project performance.

7.3 Study Management and Outreach

The study team was a multi-disciplinary group that consisted of several functional elements of the Corps and the local sponsors, and included study managers, the project manager (a wetland scientist), planners, civil design engineers, hydrologists and hydraulic engineers, environmental specialists, biologists, cost estimators, real estate specialist, economists, legal advisors, and geotechnical specialists.

The Corps and sponsor(s) conducted approximately four Steering Committee meetings and several property owner meetings each year of the study. The locally driven Steering Committee coordinated the management of the reconnaissance-level study with various Federal, state and local agencies, and environmental groups. The Steering Committee was comprised of representatives of the public, Federal, and State agencies, and special interest groups. The Committee obtained public views and comments on proposals, plans of study, scoping, impacts of proposed alternatives, and draft documents. At regular meetings during the reconnaissance study, the Steering Committee informed interested parties of the project's progress to avoid misunderstandings. Local news reporters and congressional staff attended many of the meetings.

At the Reconnaissance Review Conference held March 31, 1994, eight representatives from private industry, private property owners, environmental agencies and organizations, and Teton County traveled to Portland, Oregon, to express interest in the approval of a feasibility-level study.

The local representatives, Teton County Commissioners Steve Thomas and Grant Larson, have stated clear support for the feasibility and implementation phase.

Much of the coordination efforts have focused on scoping the study to a cost level affordable to the county. Don Barney, Teton County Road and Levee Supervisor, and Rik Gay, Teton County Conservation District, have provided guidance and leadership at the local level. Mr. Michael Gierau, and most recently Bob Sherwin, Teton County Commissioners, have provided continuity

from the previous (November 1994) Commission to the present Commission. The Walla Walla District met with the Commissioners on August 14, 1995, to further define the county's concerns and financial ability, and have executed the feasibility study accordingly.

The study has received considerable media attention, which was facilitated and coordinated by the sponsor's PR person and Corps PAO. Three notable features/articles have been published in the May 1998, *New York Times* Science; an article in *Spirit Magazine, Southwest Airlines* of May 1999; and a feature from the January-February issue of Ingersoll-Rand's technical publication, *Compressed Air* (see copy in supplemental section of this report).

7.4 Alternative Formulation Briefing Review Conference

An Alternative Formulation Briefing (AFB) Review Conference was held in Portland, Oregon on July 22 and 23, 1999. The AFB served to present the methodological approaches applied in the study's various technical analyses and to ensure that the study was proceeding in compliance with Corps of Engineers planning and policy regulations. Conference attendees from the Corps of Engineers included representatives from HQUSACE, Northwestern Division, and Walla Walla District offices. Other participants in the conference included representatives of Teton County, Wyoming (study sponsor), Teton Conservation District (study sponsor), the National Fish and Wildlife Foundation, and local citizens.

The AFB was held to discuss and resolve issues identified in the review of a 75 percent draft version of the Jackson Hole Environmental Restoration Study feasibility report and technical appendices to facilitate and accelerate the completion of the final feasibility report. Major issues identified included:

- Need for certified independent technical review documentation.
- Need for additional documentation of environmental habitat studies and trends.
- Need for discussion of relationship of proposed restoration features to surrounding ecosystem.
- Need for resolution of ability to use existing flood control levee easements for restoration project.
- Need for development of a comprehensive Real Estate Report (REP).

- Need for documentation of proposed schedule for construction phasing.
- Need for a complete list of local cooperation items in the report.
- Need to address potential efficiencies related to Federal and non-Federal maintenance responsibilities for the flood control and restoration projects.
- Need to address standards for utilization of tools developed in conjunction with the restoration project in locations along the Snake River outside the four specific study areas.
- Need to address permitting requirements in association with the Omaha Regulatory office with the goal of developing conditions for a Section 404 permit(s) for the use of restoration tools employed by this project to be used in development of regional permits for use by other interests.
- Need to address adaptive management and monitoring program.

Following the AFB, each of the above review items was addressed in preparation of a final draft feasibility report, which was submitted to HQUSACE for policy compliance review, along with documentation of the Independent Technical Review and a compliance memorandum indicating how and where each of the comments were addressed in the report.

7.5 Study and Review Teams

This section summarizes the technical review accomplished during the course of the feasibility study. This review process has involved the local sponsor(s), Corps technical staff, peer review from resource agencies and other interested parties, and formal independent technical review by the study's Independent Technical Review Team comprised of members from the Corps of Engineers and the private sector. Participating agencies in development and review of the study are listed below in Table 7.1. Table 7.2 lists the individual participants on the study and review teams. 7.6 Review Milestones

Table 7.1 – Participating Agencies in Feasibility Study and Review

Corps of Engineers (Corps)	HQUSACE
	Northwestern Division
	Walla Walla District
Teton County **Local Sponsor (LS)**	Teton County Natural Conservation District Project Steering Committee

Table 7.1 – Participating Agencies in Feasibility Study and Review (con.)

Resource Agencies (RA)	U.S. Fish and Wildlife Service
	Wyoming Game and Fish
	U.S. Environmental Protection Agency
	U.S. Bureau of Land Management
	U.S. Bureau of Reclamation
	Wyoming Ecology Department
	U.S. National Park Service (Teton)
	U.S. National Forest Service
Other Interested Parties (OIP)	Private Property Owners (38 w/in project area)
	Trout Unlimited
	Jackson Hole Conservation Alliance
	Greater Yellowstone Coalition
Private Contractors (PC)	Tetra Tech, Inc. Infrastructure Group
	Normandeau Associates

Table 7.2 - List of Study Team and Technical Review Team Personnel

Name	Grade	Discipline	Organization	Name	Grade	Discipline	Organization
W. MacDonald	GS-12	Plan Form/Team Lead	PD	T. Davis	GS-15	Chief, Planning Division	Walla Walla District
D. Barney	Sponsor	Team Leader	SPONSOR	D. Wagner	GS-14	Planner	Walla Walla District
R. Gay	Sponsor	Team Leader	SPONSOR	K. Chesney	GS-13	Biologist	Walla Walla District
B. Tice	GS-09	Fishery Biologist	PD	M. Zook	GS-14	Real Estate	Walla Walla District
R. Tracy	GS-11	Cultural	PD	J. Daniels	GS-15	Planner	HQUSACE
R. Smith	GS-11	Env. Res. Spec.	PD	W. Bayert	GS-15	Real Estate	HQUSACE
S. Ackerman	GS-12	Wildlife Biologist	PD	M. Mckevitt	GS-14	Biologist	HQUASCE
G. Ellis	GS-12	Economist	PD	F. Einerson	GS-15	Biologist	HQUSACE
C. Sneider	GS-12	Structural Design	EN-DB-SC	T. Euston	Contract	Biologist	Normandeau
B. Williams	GS-12	Structural Design	EN-DB-SC	R. Robinson	Contract	Planner	Tetra Tech
K. Callan	GS-14	Cost Engineer	EN-CB	M. Williams	Contract	Planner	Tetra Tech
L. Cunningham	GS-12	Hydrologist	EN-H	D. Lantz	Contract	Hydrologist	Tetra Tech
D. Reese	GS-13	Hydrologist	PL-H	K. Price	Contract	Hydraulic Engineer	Tetra Tech
F. Buerstatte	GS-12	Real Estate	RE	M. Gorecki	Contract	Economist	Tetra Tech
J. Smith	GS-13	Legal-Environmental	OC	T. Weeks	GS-13	Legal-Environmental	OC
R. Carlton	GS-13	Real Estate	RE	R. Jeffrey	GS-11	Program Analyst	PM-PPM
B. Miller	GS-13	Engineer	ED-D-ME				

During the course of the Feasibility phase study, there has been on-going, independent technical review of the major report products as they have become available. Major review milestones with reviewing entity and date of review are provided in Table 7.3.

Table 7.3 - Review Milestones

Product	Review Entity	Date Completed
Project Study Plan	CORPS, LS, RA, OIP	11/96
Hydrology Report	CORPS, LS, RA, OIP	11/98
Groundwater	CORPS, LS	5/91
Engineering Report	CORPS, LS, RA, OIP	11/98
Environmental Assessment	CORPS, LS, RA, OIP	3/99
Economic Analysis (Draft)	CORPS, LS	6/99
Feasibility Report (50% Draft)	CORPS, LS	3/99
AFB Conference (75% Draft Feasibility Report)	CORPS, LS, OIP, PC	7/99
Independent Technical Review (Economics)	PC	9/99
Independent Technical Review (Engineering)	PC	9/99
Independent Technical Review (Environmental)	PC	10/99
Independent Technical Review (Real Estate Plan)	CORPS	11/99
Independent Technical Review (Cost Engineering)	CORPS	11/99
AFB Review Compliance Memorandum	CORPS	11/99
Independent Technical Review Certification	COPRS	01/00
Legal Certification	CORPS	01/00
HQUACE Policy Compliance Approval	CORPS	01/00

7.7 Independent Technical Review

Walla Walla District has completed technical review of the *Draft Feasibility Report* for the Jackson Hole Environmental Restoration Study dated December 1999. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project, as defined in the study's quality control plan. During the independent technical review, compliance with established planning principals and procedures, utilizing justified and valid assumptions, was verified. This included review of assumptions, methods, procedures, and material used in analyses, alternatives evaluated, the appropriateness of data used, the level of data obtained, and reasonableness of the results. The independent technical review was accomplished by an independent team including members from Walla Walla District and contractors from Tetra Tech Inc. and Normandeau Associates.

The primary focus areas for independent technical review of the Jackson Hole Environmental Restoration Feasibility Study were environmental studies, economic studies, hydrologic and hydraulic studies, cost engineering, and real estate. A team of qualified and experienced independent reviewers provided technical review comments for each of these categories. The review comments and all actions taken were recorded were and included in a Certification of Independent Technical Review memorandum on file with the project manger.

The nature of most comments was to ask for additional documentation or explanation of study methods and findings. Many comments were editorial in nature. None of the comments identified significant shortcomings or errors in study methods or findings. All concerns resulting from independent technical review of the draft feasibility report have been considered and addressed in the final report (and summarized in the attached Technical Review Comments forms) and then back-checked by the reviewer. In addition to the primary focus areas identified above, all associated documents required by the National Environmental Policy Act have also been fully reviewed.

7.8 Policy Compliance and Legal Review

Policy compliance and technical review issues identified at the Alternative Formulation Briefing were summarized in an Issue Resolution Memorandum following the conference. All issues were addressed in completion of the final feasibility report and were summarized in an Issue Resolution Compliance Memorandum submitted to Corps Northwestern Division and HQUSACE offices for review with the final report. The HQUSACE Policy Review branch will review the final report for consistency with all Corps of Engineers policy requirements. The final report has also been submitted to Walla Walla District Counsel for review and certification of the study's legal sufficiency.

8. FINDINGS AND CONCLUSIONS

8.1 Findings

Based upon the findings of this *Feasibility Study* for environmental restoration in Jackson Hole, Wyoming, two restoration plans are determined to be feasible. These two plans include the *initially proposed NER Plan*, and the more extensive *Progressive NER Plan* that is the result of subsequent management and sponsor review of this study, as well as coordinated partnering among regional agencies, interest groups, and the study team.

8.1.1 Initially Proposed NER Plan

The initially proposed NER Plan involves implementation at study Areas 1, 4, 9, and 10.

The initially proposed NER Plan is estimated to create a total of 104,277 aquatic habitat units (an increase of 20 percent) over the future without-project condition and a total of 11,464 riparian habitat units (an increase of 108 percent) over the future without-project condition. The proposed restoration will also improve habitat for multiple threatened and endangered species that depend on healthy and diverse river-related ecosystems. Threatened and endangered species that have been witnessed or may occur in the project area include the bald eagle, peregrine falcon, whooping crane, grizzly bear, and gray wolf.

The initially proposed NER Plan is estimated to have a total cost of $26.23 million.

8.1.2 Progressive NER Plan

The Progressive NER Plan involves restoration of the entire 22-mile reach of the Snake River starting approximately 2 miles downstream of Moose, Wyoming, to Flat Creek at South Park National Elk Feedgrounds. This is consistent with Congressional authority to study, evaluate, and make recommendations. The Progressive Plan provides the greatest opportunity for environmental restoration of all impacted areas of the Snake River below Grand Teton National Park and above the canyon section of the river managed by the USFS.

The Progressive Plan is estimated to create a total of 398,970 aquatic habitat units (an increase of 20 percent) over the future without-project condition. The Progressive Plan will also create an estimated total of 43,862 riparian habitat units (an increase of 108 percent) over the future without-project condition. The proposed Progressive Plan will improve habitat for the threatened and endangered species (*i.e.*, the bald eagle, peregrine falcon, whooping crane, grizzly bear, and gray wolf) mentioned in the initially proposed NER Plan (see Section 7.1), but with habitats restored over the entire 22-mile reach of the Snake River. The Progressive Plan provides the opportunity for greater ecosystem influence due to the restoration of highly degraded habitat over a larger geographic area. The expanded restoration effort will provide greater synergistic effect on adjacent habitats landward of the levees.

The Progressive Plan will use a phased construction approach, implementing restoration in Areas 1, 4, 9, and 10 before Areas A through H. The Progressive Plan will enable potential local sponsors to restore sections of the river more quickly and efficiently without the cost and time required for additional feasibility studies. Advancements in ecosystem restoration will occur as a result of the Planning, Engineering, and Design phase applied to the first four study areas and lessons learned from adaptive management of those areas.

The cost per mile of restoration under the Progressive Plan varies along different parts of the river, but is within the range of costs determined for Areas 1, 4, 9, and 10. The total cost of the Progressive Plan is estimated at $52.3 million. As noted in the Draft FONSI, a factor in the elimination of the alternatives which included the additional areas suggested in the Progressive Plan was that the cost exceeded the local sponsor's current ability. The areas in the Progressive Plan will be completed based on availability of anticipated funding of the local sponsor and the COE.

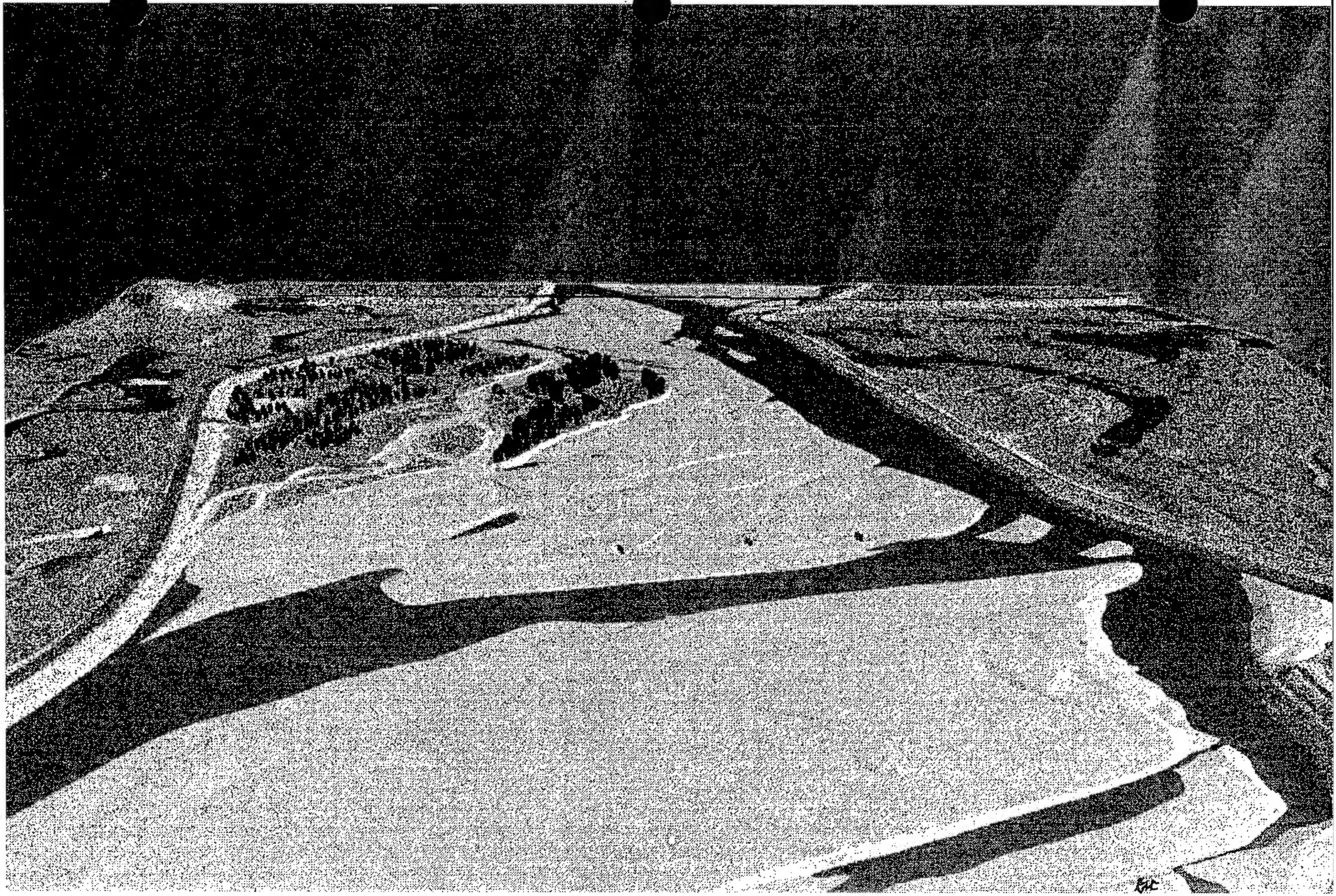
8.2 Conclusions

Both the initially proposed NER Plan and the Progressive NER Plan will restore and protect important fish and wildlife habitats impacted by the Snake River Federal Flood Control Project. Both plans will provide restored habitats for multiple threatened and endangered species. Both plans will enhance diversity of animal and plant species in a geographical area in which fishing and nature-related recreation play a large part in regional and national economies. The Progressive Plan will result in optimal restoration over a more extensive portion of this

outstanding natural environment. Based upon this *Feasibility Study*, implementation of the Progressive NER Plan is recommended

This conclusion reflects the information available at this time and current Corps policies governing formulation of individual projects. The conclusion does not reflect program and budget priorities inherent in the formulation of a national Civil Works construction program or the perspective of higher review levels within the Executive Branch. Consequently, the conclusion may be modified before implementation.

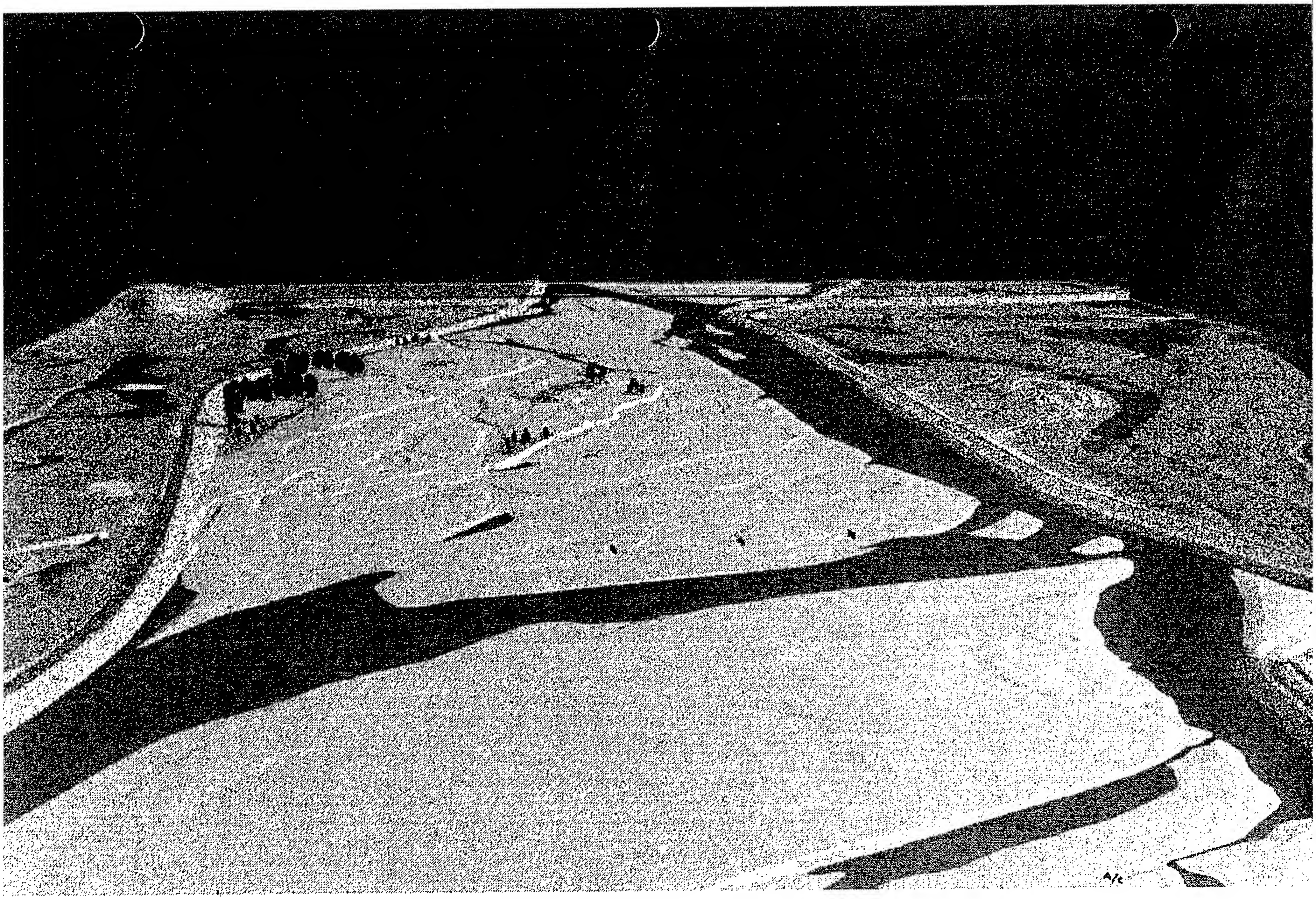
William E. Bulen, Jr.
Lieutenant Colonel, Corps of Engineers
District Engineer



SITE 9 EXISTING (1996): VIEW LOOKING DOWNSTREAM

U.S. Army Corps of Engineers
Walla Walla District

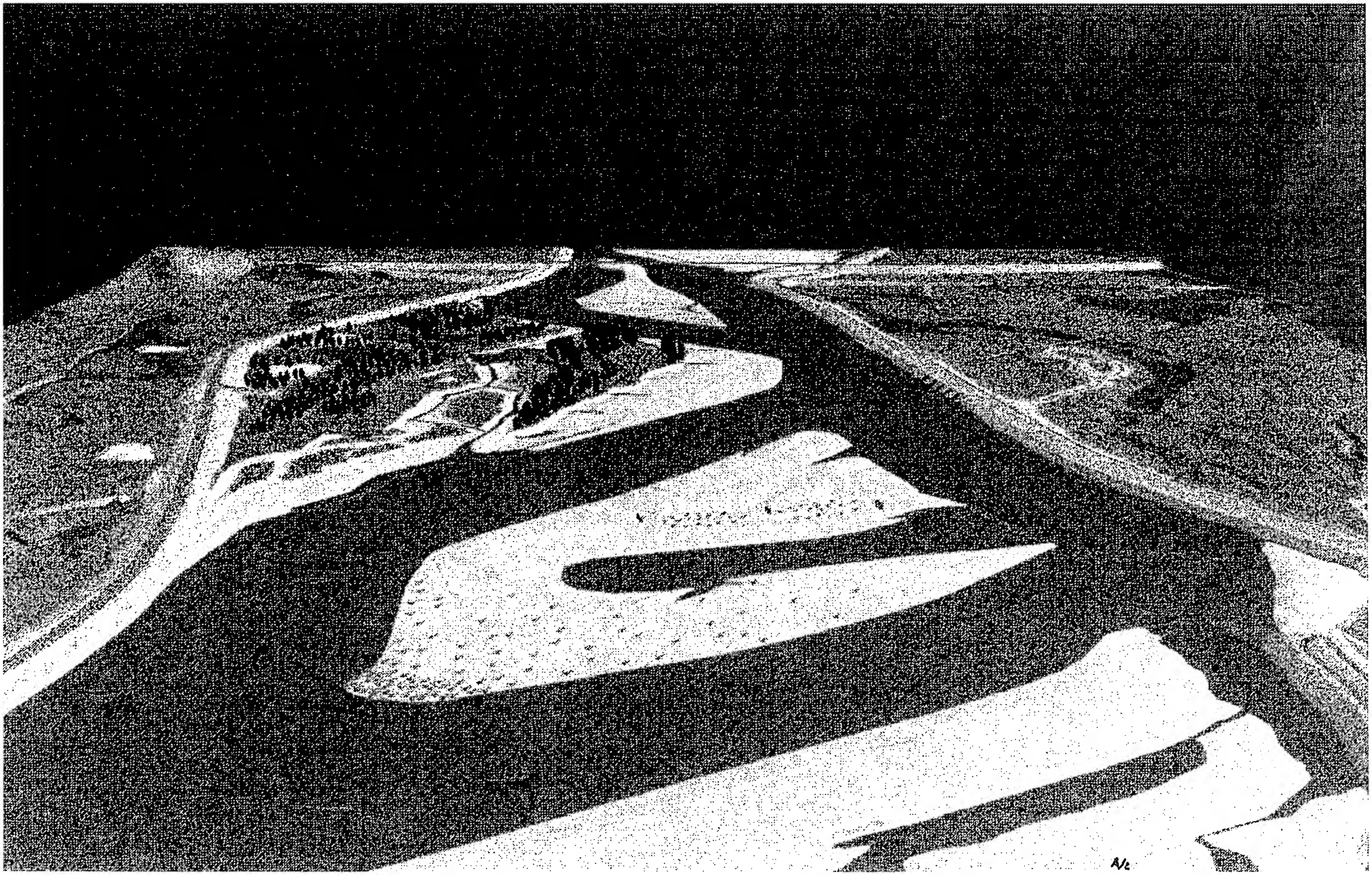
PLATE 20



SITE 9 NO ACTION/YEAR 2050: VIEW LOOKING DOWNSTREAM

U.S. Army Corps of Engineers
Walla Walla District

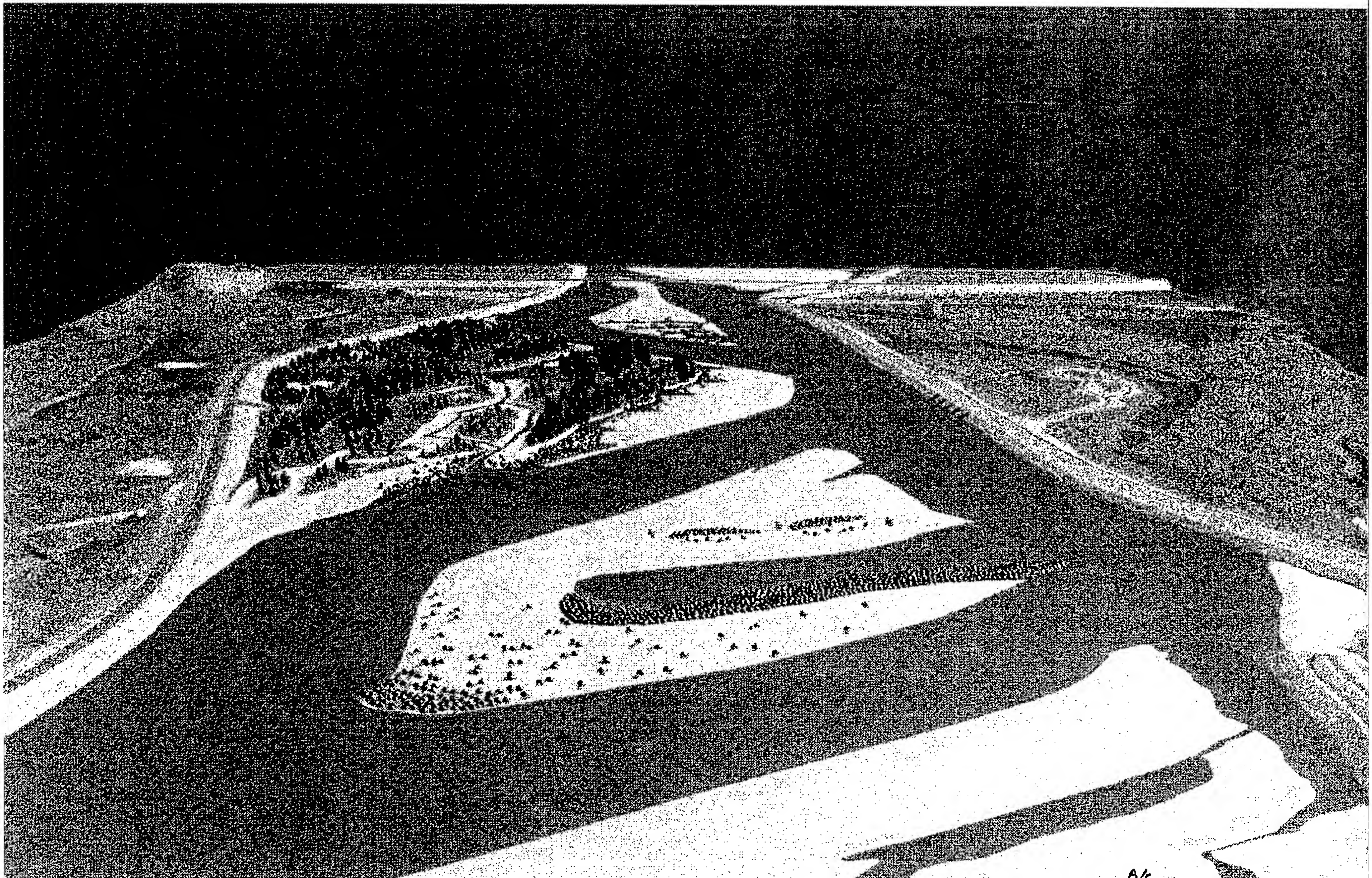
PLATE 21



SITE 9 WITH-PROJECT 0-YEAR: VIEW LOOKING DOWNSTREAM

U.S. Army Corps of Engineers
Walla Walla District

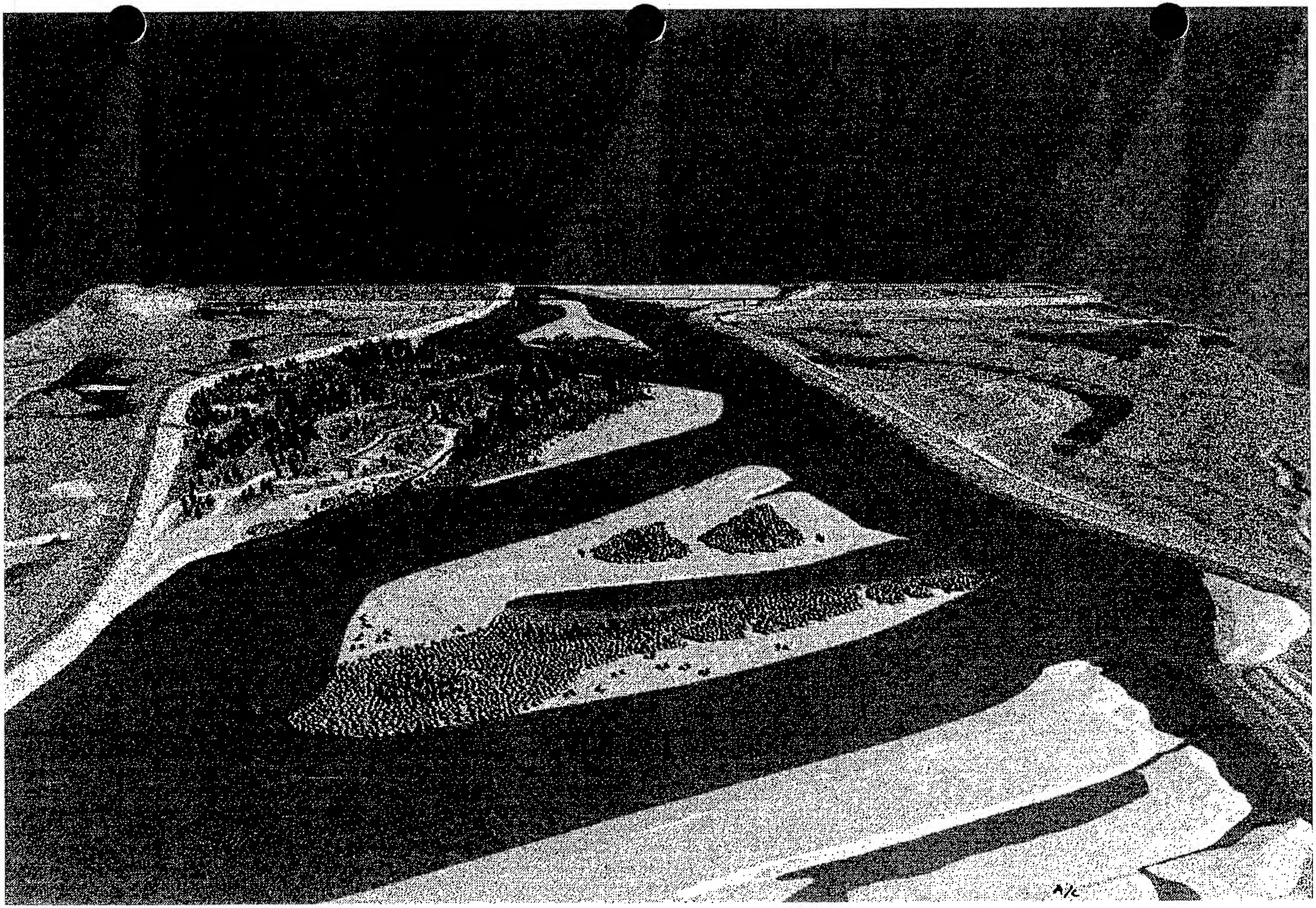
PLATE 22



SITE 9 WITH-PROJECT 5-15 YEAR VEGETATION: VIEW LOOKING DOWNSTREAM

U.S. Army Corps of Engineers
Walla Walla District

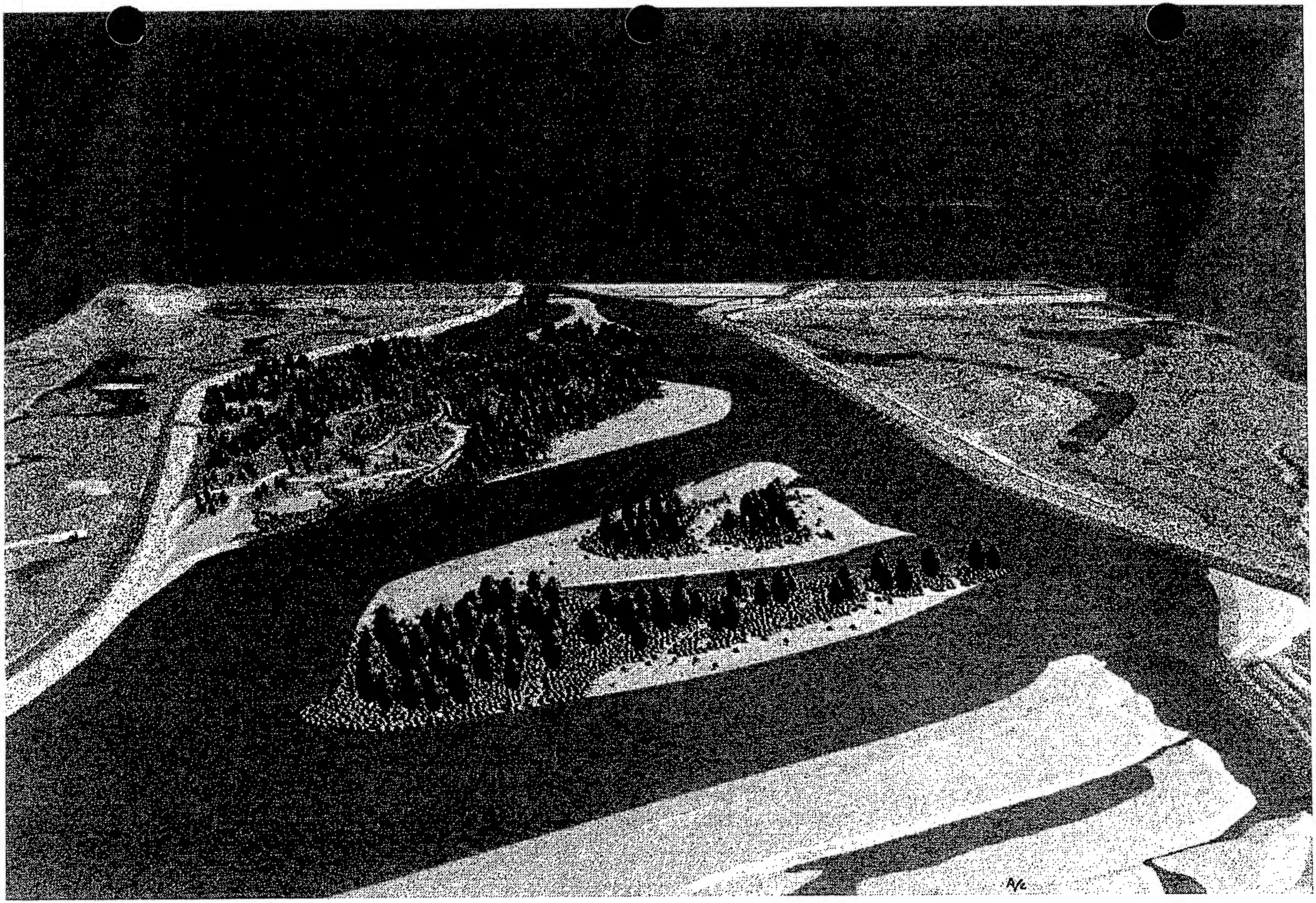
PLATE 23



SITE 9 WITH-PROJECT 25-YEAR VEGETATION: VIEW LOOKING DOWNSTREAM

U.S. Army Corps of Engineers
Walla Walla District

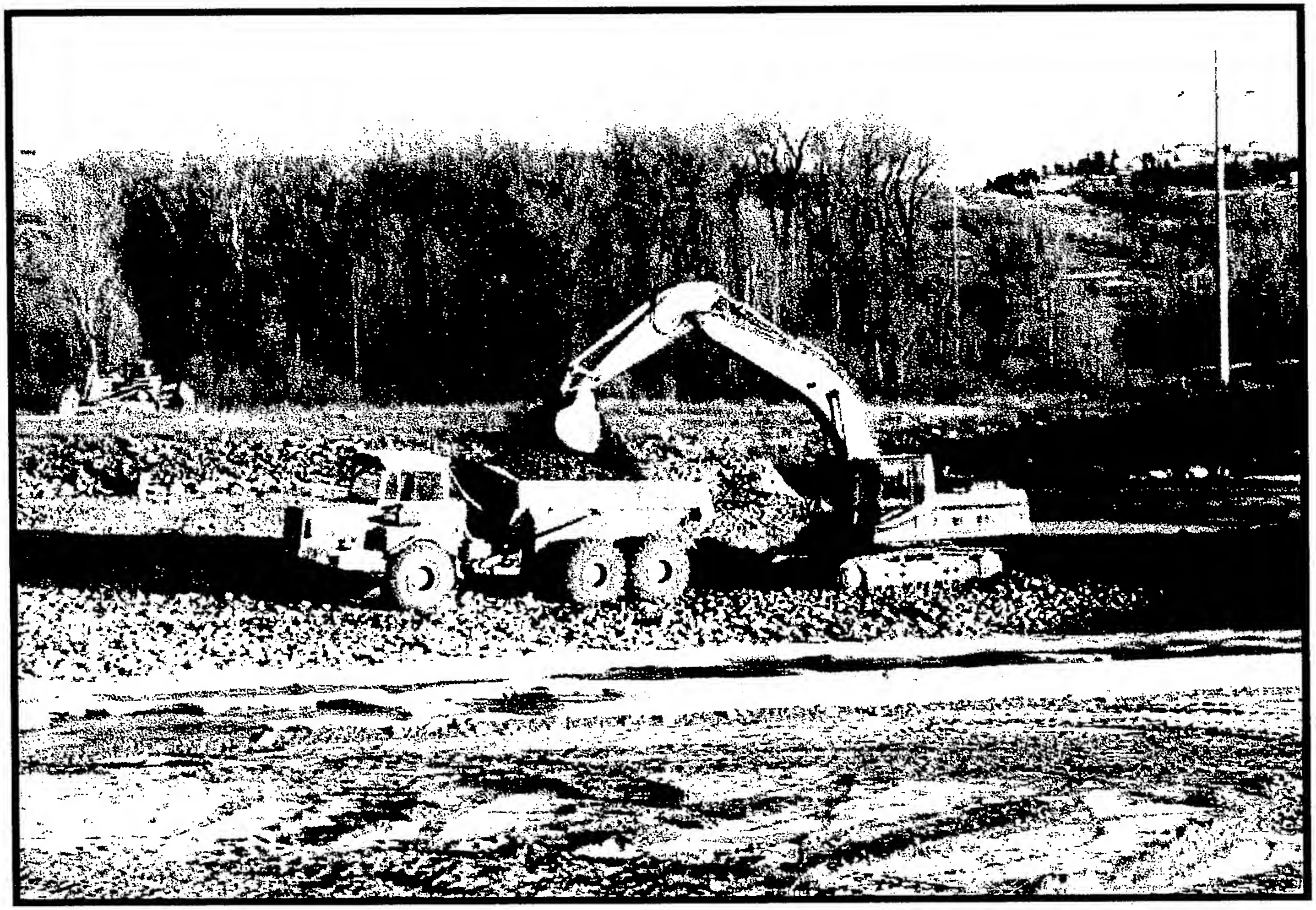
PLATE 24



SITE 9 WITH-PROJECT 50-YEAR VEGETATION: VIEW LOOKING DOWNSTREAM

U.S. Army Corps of Engineers
Walla Walla District

PLATE 25



Demonstration Project Site 9: Post-construction photo from November, 1998

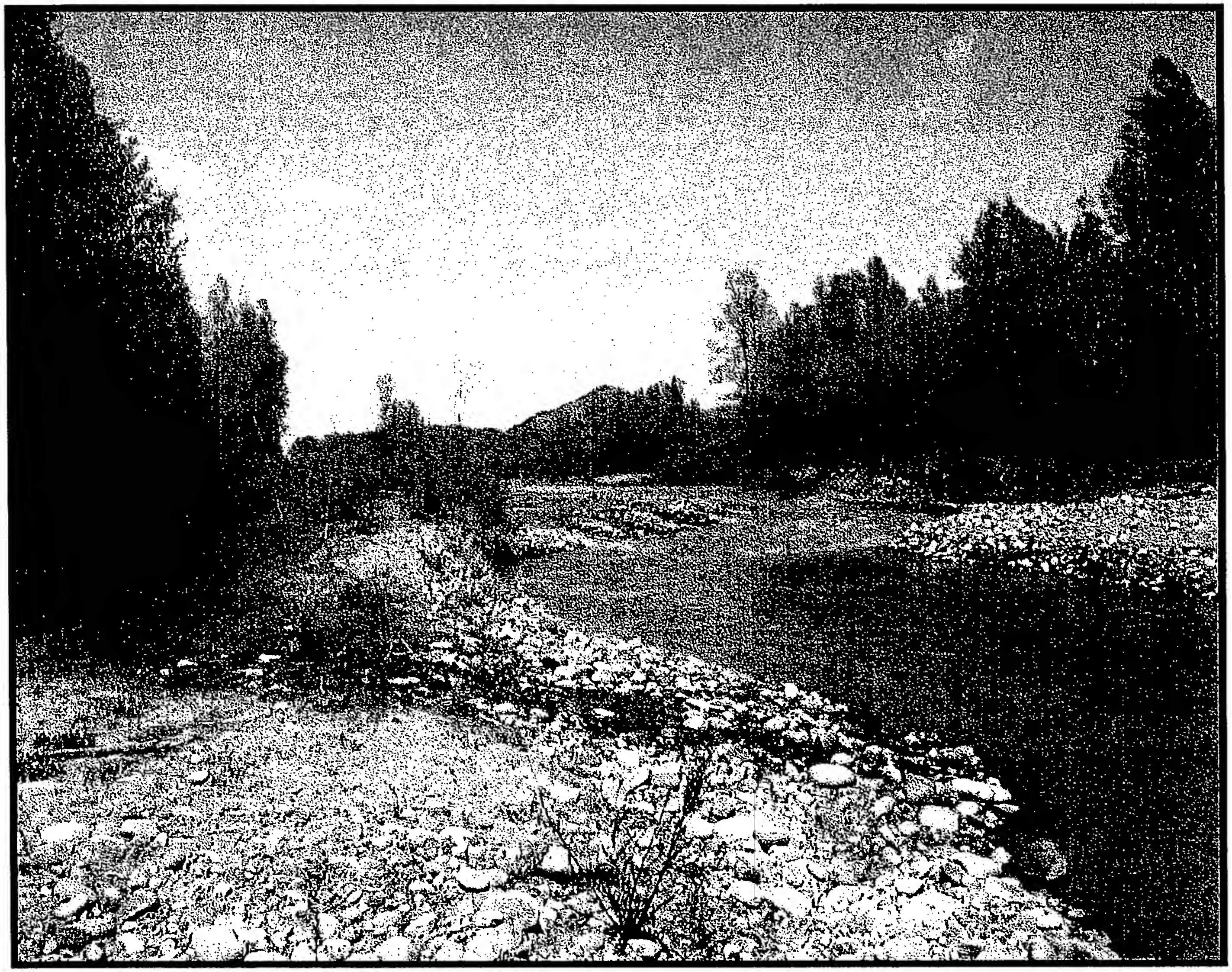
U.S. Army Corps of Engineers
Walla Walla District

Teton County Wyoming

TCNRD

Jackson Hole, Wyoming
Non-Federal Sponsor Demonstration Project
December 1999

Plate 26:
Channel Capacity Excavation



Demonstration Project Site 9: Photo from 27 May, 1999; 14,000 cfs flow

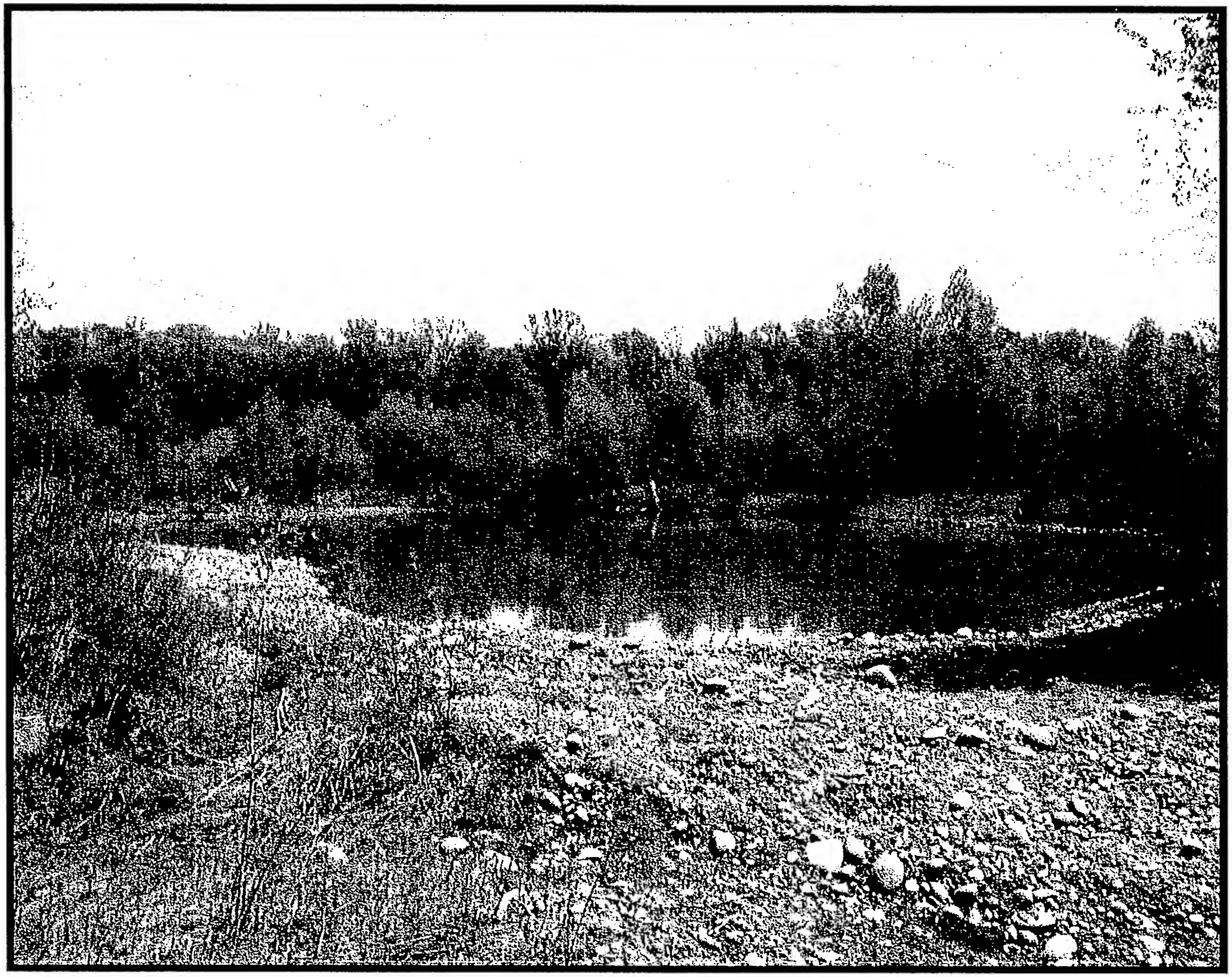
U.S. Army Corps of Engineers
Walla Walla District

Teton County
Wyoming

TCNRD

Jackson Hole, Wyoming
Non-Federal Sponsor Demonstration Project
December 1999

Plate 27:
Side Channel Pool



Demonstration Project Site 9: Photo from 27 May, 1999; 14,000 cfs flow

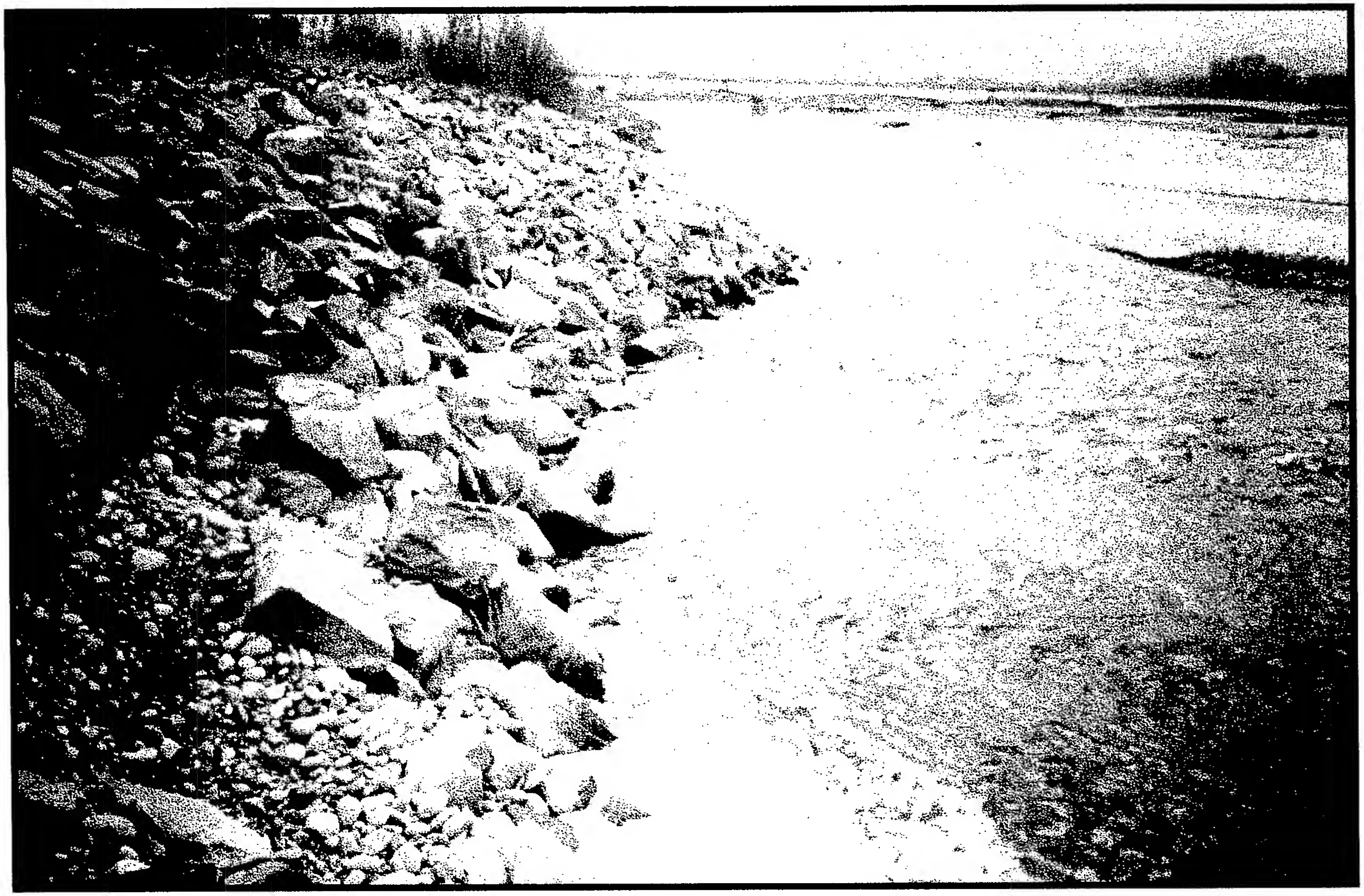
U.S. Army Corps of Engineers
Walla Walla District

Teton County Wyoming

TCNRD

Jackson Hole, Wyoming
Non-Federal Sponsor Demonstration Project
December 1999

Plate 28:
Off-Channel Pool



Demonstration Project Site 9: Photo from November 1998; 5,000 cfs flow

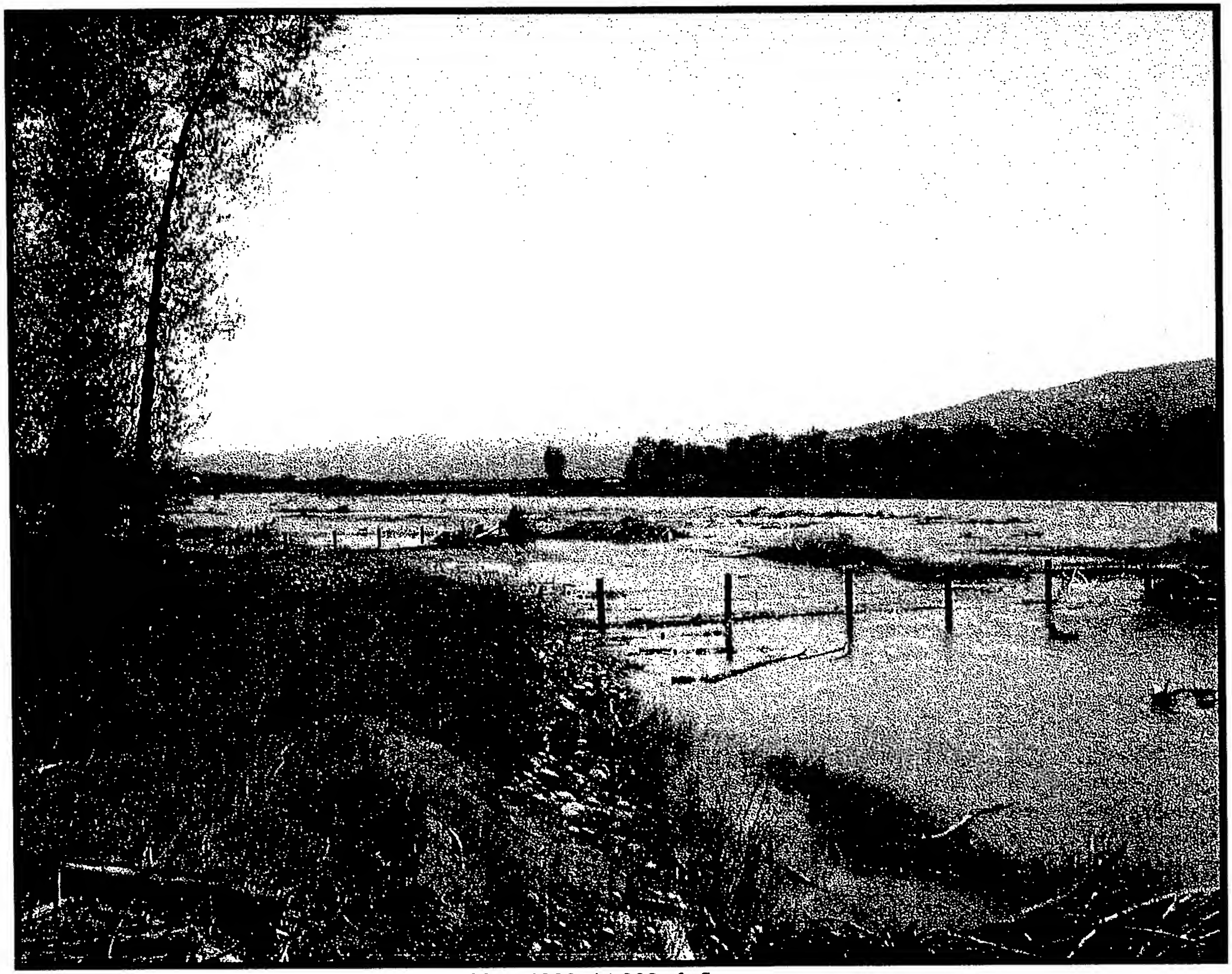
U.S. Army Corps of Engineers
Walla Walla District

Teton County Wyoming

TCNRD

Jackson Hole, Wyoming
Non-Federal Sponsor Demonstration Project
December 1999

Plate 29:
Rock Spur Dike



Demonstration Project Site 9: Photo from 27 May, 1999; 14,000 cfs flow

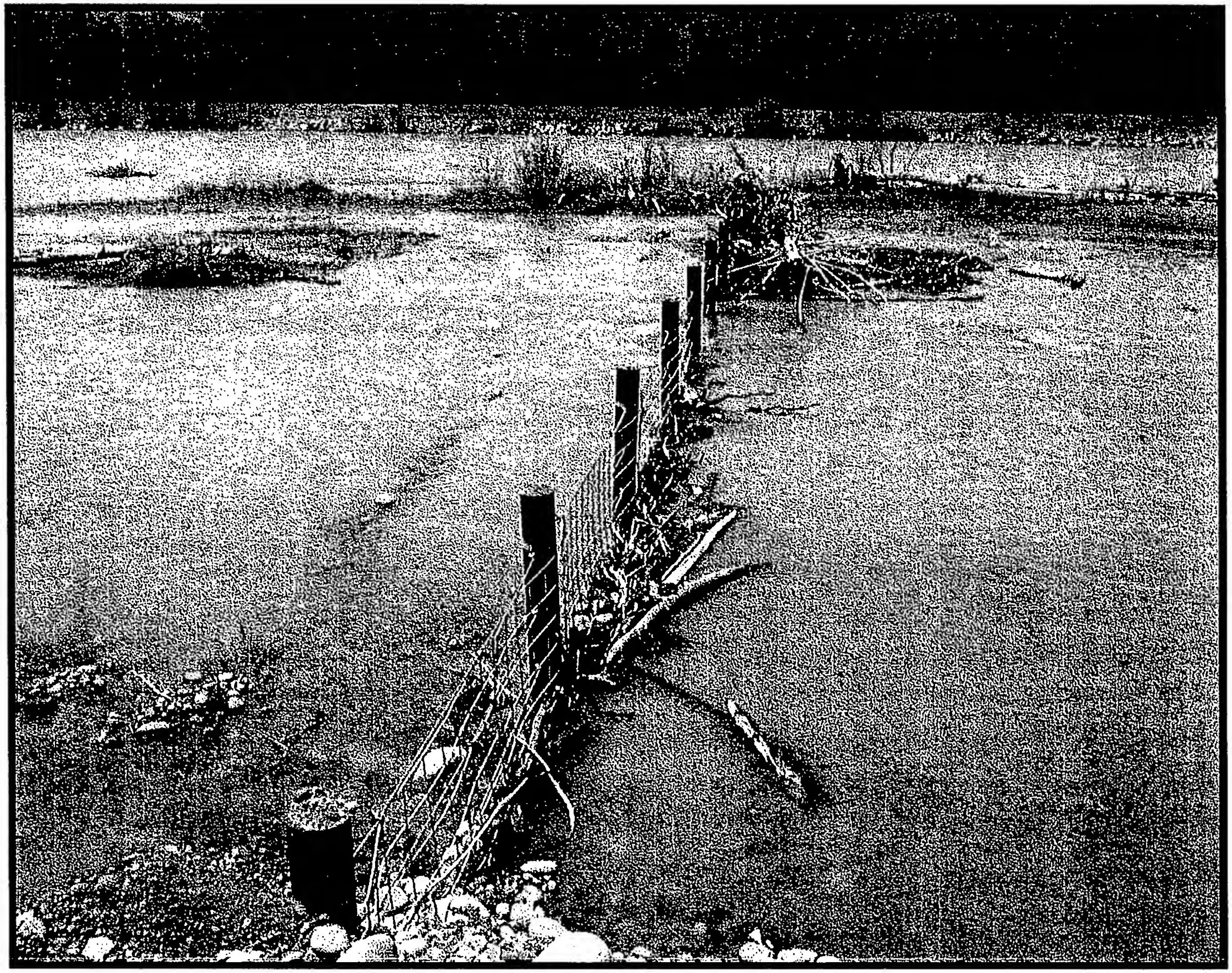
U.S. Army Corps of Engineers
Walla Walla District

Teton County Wyoming

TCNRD

Jackson Hole, Wyoming
Non-Federal Sponsor Demonstration Project
December 1999

Plate 30:
Eco Fence



Demonstration Project Site 9: Photo from 14 June, 1999; 16,000 cfs flow

U.S. Army Corps of Engineers
Walla Walla District

Teton County Wyoming

TCNRD

Jackson Hole, Wyoming
Non-Federal Sponsor Demonstration Project
December 1999

Plate 31:
Eco Fence with Debris

Demonstration Project Site 9: Post-construction photo from November, 1998

U.S. Army Corps of Engineers
Walla Walla District

Teton County Wyoming

TCNRD

Jackson Hole, Wyoming
Non-Federal Sponsor Demonstration Project
December 1999

Plate 32:
Eco Fence with Large Debris

Demonstration Project Site 9: Post-construction photo from November, 1998

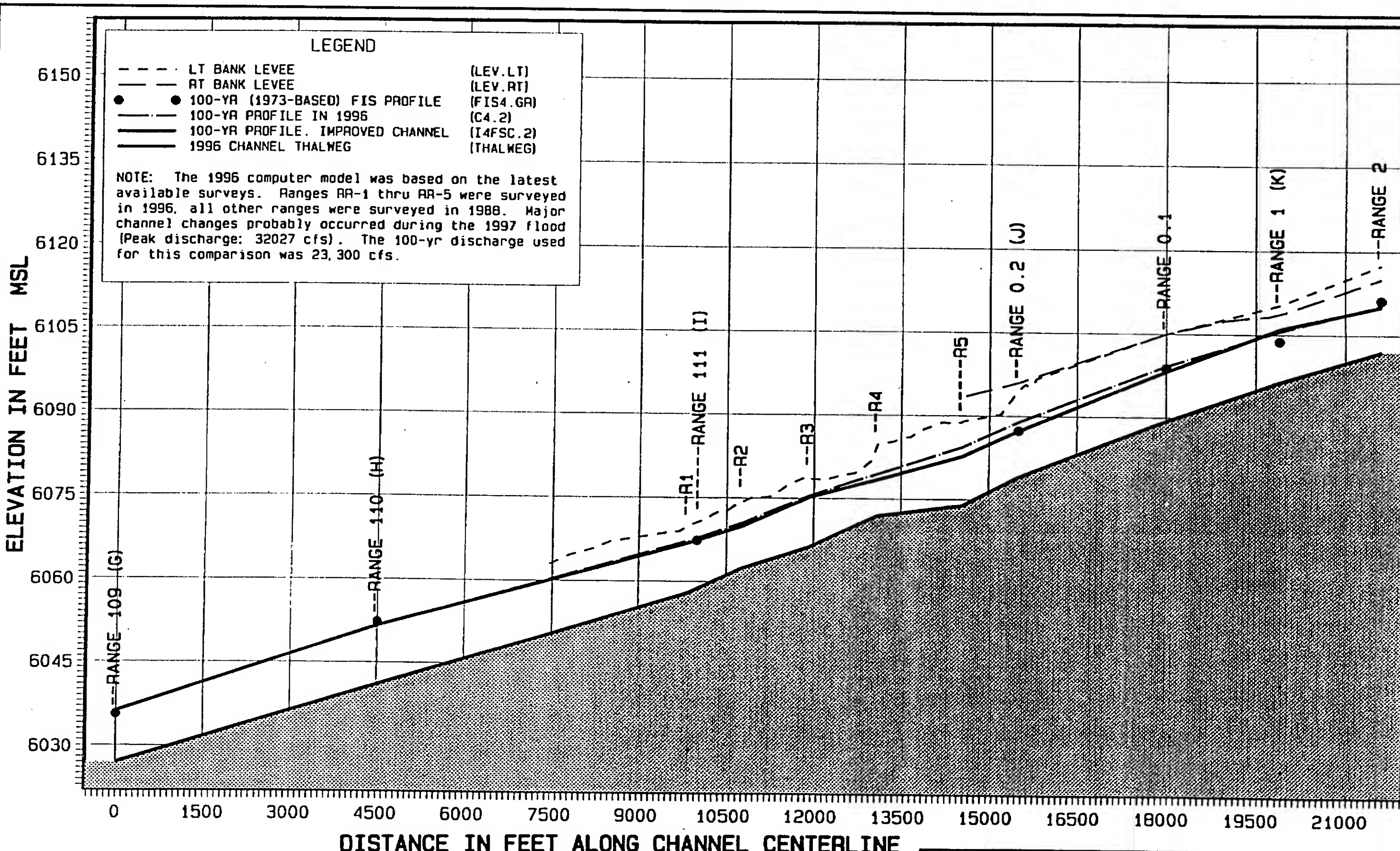
U.S. Army Corps of Engineers
Walla Walla District

Teton County Wyoming

TCNRD

Jackson Hole, Wyoming
Non-Federal Sponsor Demonstration Project
December 1999

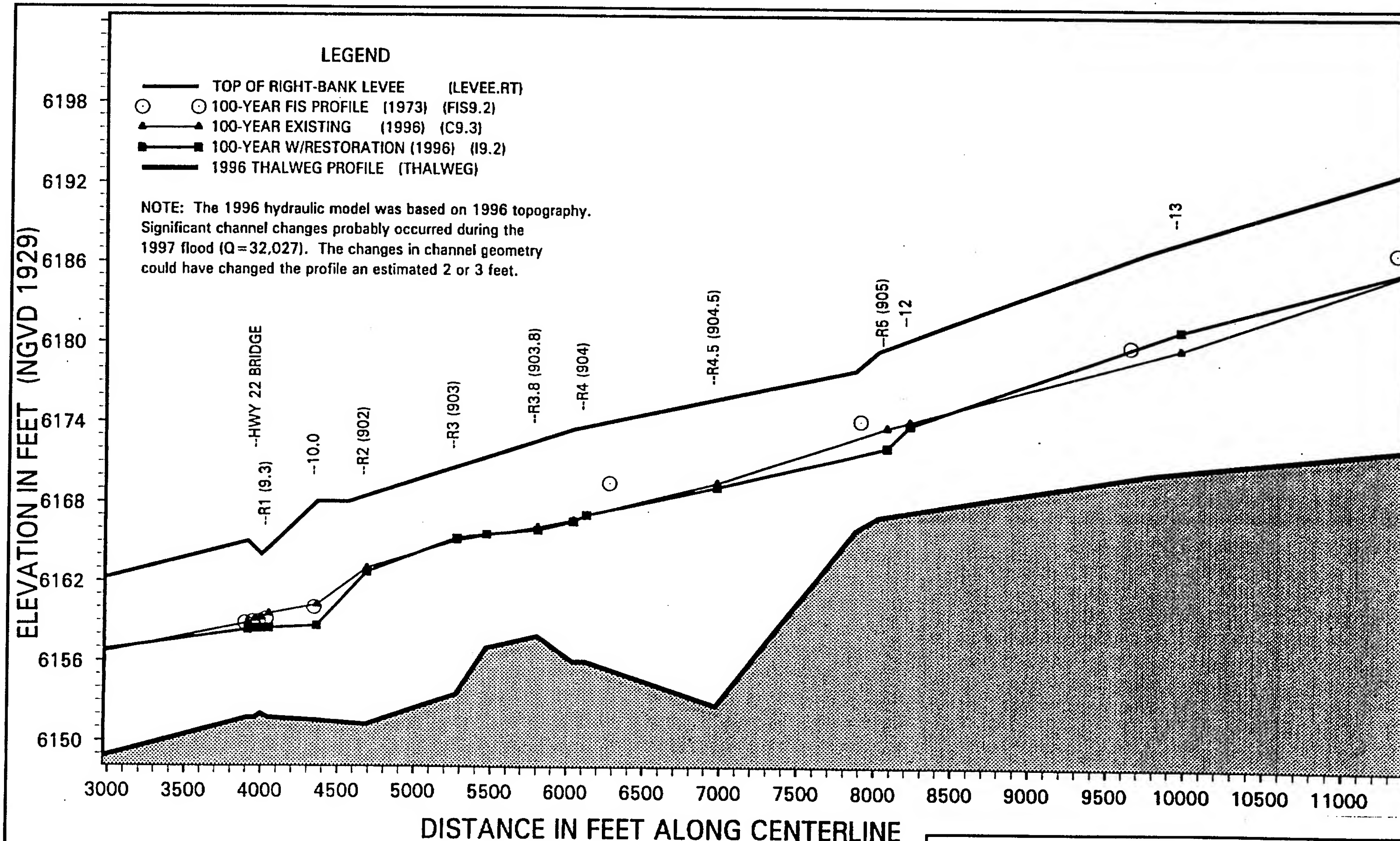
Plate 33:
Rootwad



Jackson Hole, Wyoming
Environmental Restoration Study
December 1999

Plate 34:
Area 4: 100-Year Flood Profiles
With and Without Restoration Measures

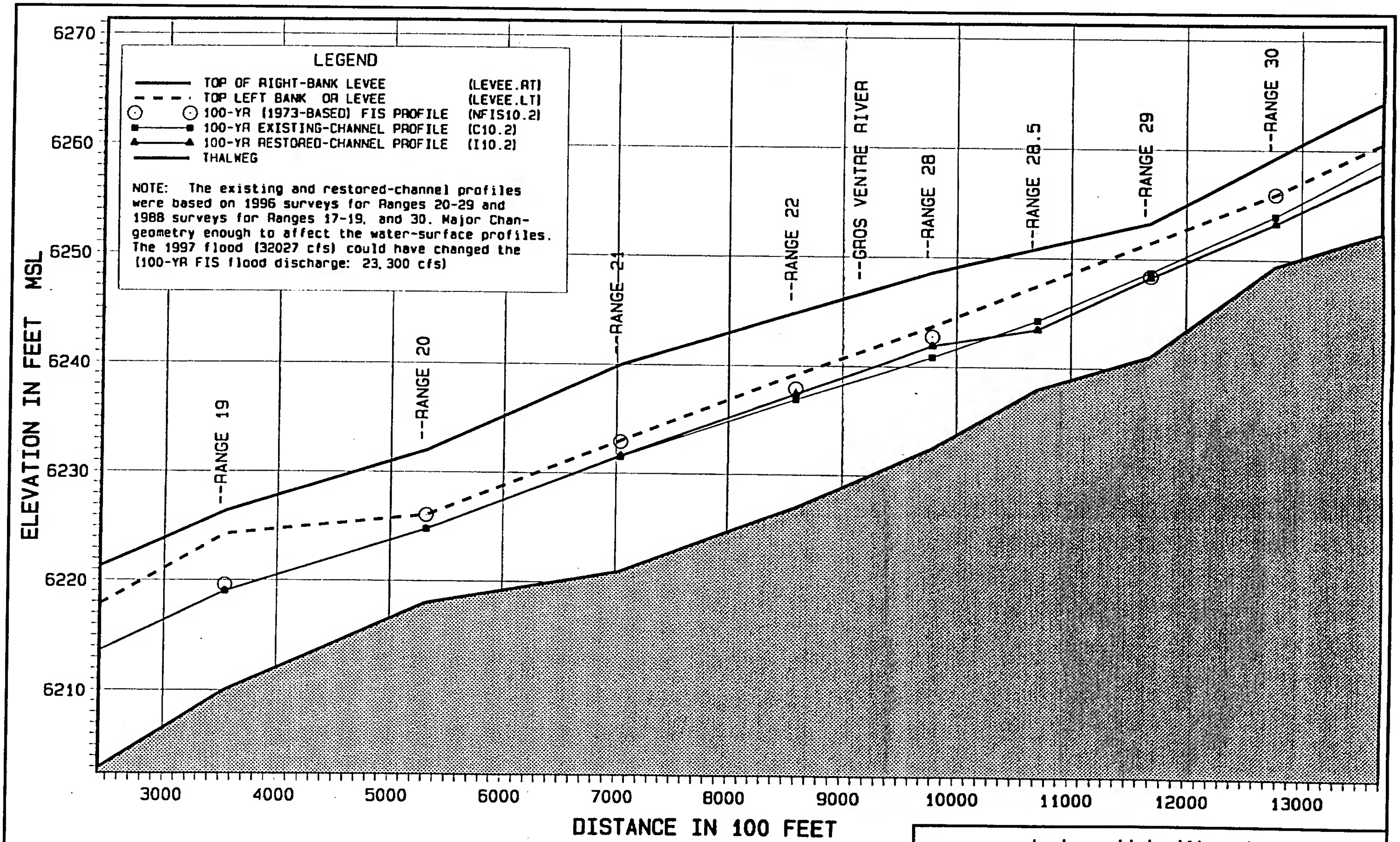
U.S. Army Corps of Engineers
Walla Walla District



U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study
December 1999

Plate 35:
Area 9: 100-Year Flood Profiles
With and Without Restoration Measures



U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study
December 1999

Plate 36:
Area 10: 100-Year Flood Profiles
With and Without Restoration Measures

Final Report

Prepared January 2000

by
Rik Gay
Executive Director, Teton Conservation District

Snake River Restoration

Demonstration Project #99-068

6/4/99

This set of three panoramas is the upper part of the brush fence area and provides evidence of how well the fences captured silt. The first series was taken at river flows of 15,900 cubic feet per second. The water had only appeared the day before in the fenced area and is "subbing" up e.g. ground water pooling at this point. Note the distance the main channel of the river is from the end of the fences. At low flow the edge of the channel was at least 40 meters from the fence in this location.

6/25/99

The second series (17,200 cfs) was taken the first day after peak runoff that the site could be accessed (20,600 at 6/18/99). The fenced area has had river flows passing through for about 15 days at this point. Note that heavy current impinging on the end of the fence at left and that the main channel of the river is trying to shift into the fenced area but is being diverted away by the fences.

7/9/99

Spring runoff flows have receded to 8,800 cfs in this series. Significant deposition of nutrient rich sediment has occurred with the fences functioning as expected. However, the fences were not designed to withstand a direct attack from such high velocities as was experienced during this event which were up to 15 feet per second in this case. Prior to runoff, the main channel of the river was well out from the fenced area. As you compare this series with that taken on June 6th you can see that the main channel has completely shifted from river right to river left. Consequently, had the fences not been in place the lower third of this island would have been attacked by the main current and would have been eroded away. To have the fences function as island protection was an unanticipated bonus.

9. SUPPLEMENT

9.1 *Final Report: Snake River Restoration Demonstration Project*, by Rik Gay, Teton Conservation District

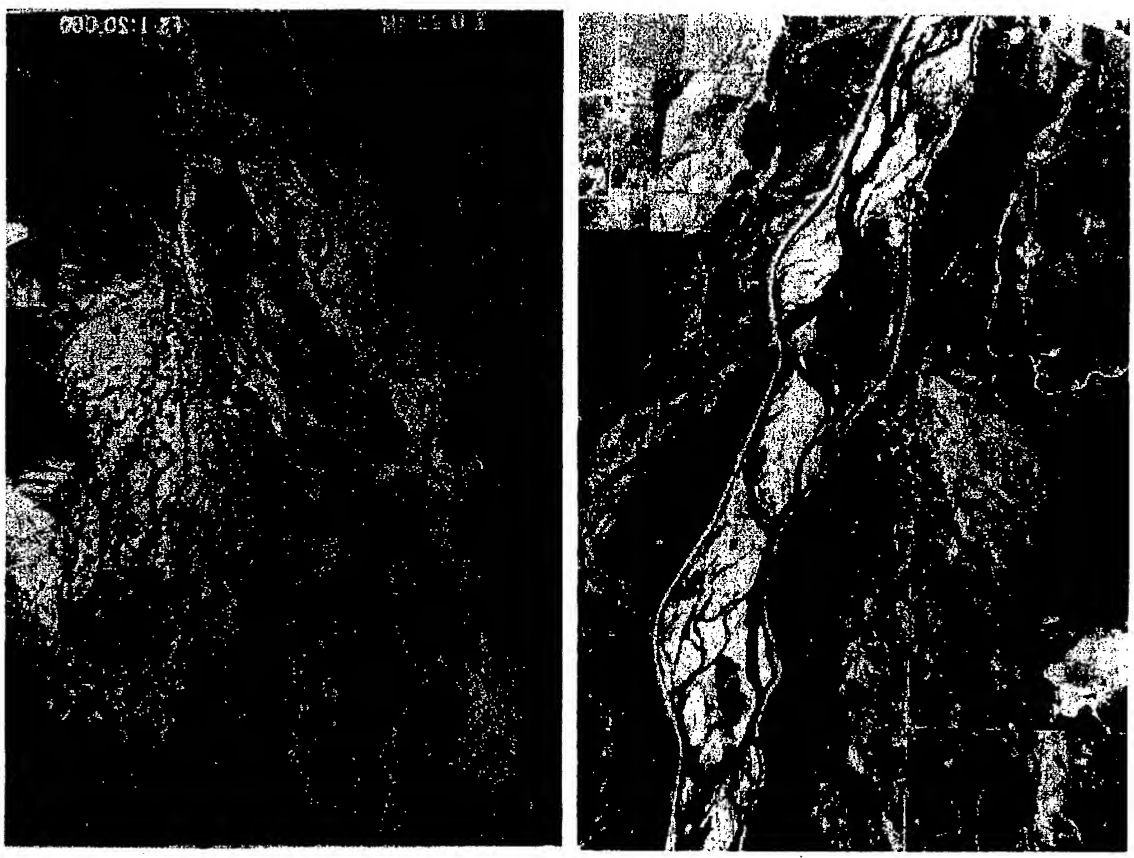
9.2 "The Good Flood," by Jim Morrison, from *Compressed Air*, January-February, 2000 published by Ingersoll-Rand

TABLE OF CONTENTS

INTRODUCTION

The Teton Conservation District (formerly known as the Teton County Natural Resource District) is involved in a collaborative environmental study of the Snake River ecosystem assessing historical, existing, and potential future conditions of the riparian, riverine, and wetland habitats. The Snake River is of particular interest for several important ecological reasons. First and foremost, the Snake is one of the few remnant strongholds for a native fish population, the Finespotted Snake River Cutthroat trout. The ecosystem also provides habitat for a great number of bird species including many different varieties of waterfowl, Bald and Golden eagle populations, Osprey, and Trumpeter swans. It also supplies important habitat for elk, moose, deer, Grizzly and Black bear.

With the increased velocities created by the constriction of the Snake River floodplain within the Federal levee system, the islands and exposed stream banks within the system have become unstable. That instability has created a loss of valuable riverine, riparian, wetland, and associated habitats, including fisheries. The net loss of these desirable habitats within the leveed reach has been estimated at approximately 80-90% since 1956.



The aerial photos above illustrate the impact the levees have had on riverine habitat. The mirror images are of the same area on the Snake River just below the Wilson bridge. The photo on the right was taken in 1955 pre-levee and the one on the left in 1978 post-levee.

Aggradation of bedload material as indicated here was occurring in a number of areas along the leveed reach. Most notably in the Gros Ventre / Snake River confluence, at the Snake River Bridge, and at the lower end of the leveed reach.

It has been established through sediment range surveys first completed in 1954 that there are several sites along Snake River's levee reach that have experienced excessive aggradation of bedload material. This aggradation causes severe channel instability and diminished flood capacity in these areas.

While a significant amount of river restoration work is taking place in many different watersheds throughout the country, to the best of our knowledge no restoration work has been attempted in a high energy braided mountain riverine system similar to the Snake river in Western Wyoming. With an average slope of 12 - 14 feet per mile and the composition of the riverbed being mainly glacial outwash or cobbles, any application of "typical" restoration measures, while considered, are not applicable to this system. Therefore any of the proposed restoration actions developed during the study of this system over the last several years is considered experimental in nature and untried. Thus the need for the "Demonstration" project.

The foundation of the demonstration project was to "field test" scaled down versions of the restoration "tools" that are being proposed in the larger Snake River Restoration Project. Both current and historical conditions in the Demonstration site have been documented through cross section survey and aerial photography providing a good basis for determining the effectiveness of the restoration tools. Using cross sections and photography taken in the Demonstration project site, the locations of several historical channels were identified. The desired condition in the area was to have two main channels running full during runoff periods to disperse runoff energy in as wide an area as possible. The channels would be defined by point bars and small islands with emergent vegetation during low flow periods.

It was also desirable to have one small low flow channel separated from the main channels by a large island with multi-story 25 – 50 year vegetative growth. This side channel would provide both spawning areas and overwintering habitat for trout. To achieve this, three sites along the low flow channel were chosen to have large pools excavated in or near the side channel. Additionally, to arrest the erosion of the main island, which provided protection for the low flow channel and ponds, it was proposed to install debris fences on the main channel side of the island. It was hoped that these fences would mimic the natural process of capturing debris and

sediments, allowing for natural vegetative growth to occur. At the same time the fences would provide the protection necessary for the vegetation to mature to the point where it could stabilize the newly formed stream bank.

This report will provide details of the project and the first year's results.

THE CONSERVATION PARTNERSHIP

The Teton Conservation District (TCD) is a legally organized Conservation District by Wyoming State Statues 11-16-101 through 11-16-134 as a legal subdivision of the State of Wyoming. As a nonprofit organization operating under locally elected District Supervisors, TCD's purpose is to develop and implement programs to protect and conserve soil, water, prime and unique farmland, rangeland, woodland, wildlife, energy and other renewable natural resources. Districts also stabilize local economies and resolve conflicts in land use. The District Supervisors address local needs through a responsible conservation ethic and are supported by the State of Wyoming. TCD has coordinated and cooperated on numerous resource oriented projects. In the past TCD has relied on federal and state partnerships but is very interested in developing long-term partnerships with non-governmental organizations to enhance the stability of our organizations future operations. This project provides not only the opportunity to benefit the resource by addressing the increasing population and development pressure, but also to showcase a conservation partnership. That partnership involves agriculture, local government, the Corps of Engineers, State and Federal wildlife resource organizations and agencies, as well as non-governmental organizations in a high profile setting that receives millions of tourists annually and receives national media attention.

The National Fish and Wildlife Foundation, through it's reputation for dedication to the conservation and management of fish, wildlife, plant resources, and the habitats on which they depend, was approached as both a short and long term partner in the current Snake River restoration effort. Interim results of the current study indicate that mitigation and rehabilitation of the varied natural habitats associated with the river can be achieved. As local sponsors, both Teton County and the Conservation District have forged a successful partnership with the U.S. Army Corps of Engineers. That partnership has been extended to local agricultural interests, whom still own a majority of the land along the river, to work together toward solutions serving conservation objectives.

The Wyoming Game & Fish Department provided important guidance in the development of the side channel habitat as well as important fisheries and water quality data for the area. Additionally, special recognition as a conservation partner needs to be given to David Owen. Without his generous contribution of equipment and time for gravel removal, screening, and replacement of oversize material, this project would not have been possible. His contribution was estimated at over $200,000.

THE RESTORATION STUDY

As co-sponsor, the Teton Conservation District is an integral part of the interagency Snake River Restoration Study. This study addresses the dynamics of the Snake River including hydrology, geology, geomorphology and the concerns over the loss of wetlands and valuable habitats along the River. The four year study began in 1996 and looked at methods of improving wetland areas, reducing the loss of riverine habitats, and conservation of existing fish habitat and the improvement of historical fisheries. This Study will ultimately lead to an ecosystem based river rehabilitation program. The overall study area runs along the leveed section (approximately 24 miles) of the Snake River from the southern boarder of Grand Teton National Park to the southern end of Jackson Hole. An objective of the study was to identify restoration methods that would not "force" the river to stabilize through direct intervention but rather to encourage stability and natural revegetation through minimally invasive measures.

In the Snake River, flow velocities in both main and secondary channels tend to be high, attributable to the general steep slope of the valley. Due to the high transport of bedload the channel complex is constantly changing. During high flows, avulsion of the main channel into side channels is a common occurrence. When flows erode gravel bars, the main channel can become clogged with debris and shift direction suddenly and unpredictably. However, the construction of the federal and non-federal levees blocked the lateral spread of the river and reduced the width of the floodplain and the degree of complexity of the braided system. This limited the ability of the channel to migrate and restricted avulsion activity to the area between the levees. This concentrates the flow in the main channel of the river during runoff thereby increasing the frequency of erosive attacks upon the islands and vegetation between the levees. These artificially high energy flows and subsequent erosion prevents the natural recovery of the islands and vegetation within the river system. Bedload material brought into suspension by turbulent flow are now more likely to be carried through the system rather than be carried laterally into the slower secondary channels where the material could be redeposited over a wider area of the floodplain.

Upon review of the preliminary data during the study, including historic cross sections and aerial photography, a number of promising restoration concepts were developed. These "tools" such as planned channel excavation, pool creation, debris fences, and kicker dikes were designed to restore and protect stream bank riparian habitat in the Snake River. They had the potential to stabilize historic river channel configurations, restore flood flow carrying capacity, improve pool/riffle ratios, and enhance fish habitat while decreasing flow impingement pressure on levees. To test the experimental nature of the designs, the Demonstration Project was created to demonstrate the effectiveness of the restoration "tools" on a reduced scale prior to the completion of the overall study. Therefore if any modification were necessary then changes could be made before implementing the restoration plan in it's entirety.

THE DEMONSTRATION PROJECT

The Demonstration Project, which provided an opportunity to test proposed rehabilitation methods and contributed new information, was completed in the Fall/Winter of 1998 in the area of the Wilson Bridge on the Snake River. The Demonstration Project had three main objectives. The first objective being stabilization and restoration of streambank and riparian habitats along the Snake River by encouraging the natural island rebuilding processes (successional processes). Upstream of the Wilson bridge it was proposed to restore an existing island to pre-1986 surface area, an increase of approximately two acres. This was accomplished through by the use of pile driven "brush fences". The fences snag and trap woody debris during peak spring flows thereby reducing water velocity, causing silts and sediments to be deposited. Newly deposited sediments create a favorable environment for "volunteer" wetland and scrub-shrub vegetation. The wetland/scrub-shrub plant community will trap additional sediments which will in turn promote riparian cottonwood growth and stabilize streambank.

A secondary objective is stabilization of the river channel and restoration of the flood capacity in the area of the Wilson Bridge. This was accomplished through planned extraction of riverbed material to encourage enhanced channel stability and restore the carrying capacity of the levee reach in the Wilson bridge area[1]. An estimated 54,000 cubic yards of bedload material was to be removed from an aggraded area immediately adjacent to, and extending up the west bank upstream of, the Wilson bridge. The bedload material was to be transported to the existing gravel processing site adjacent to the proposed restoration area and processed for the purpose of separating all material ≥4" in diameter. This oversize material was returned to the excavated channel to aid in the natural "armoring" of the river channel. The final objective was to improve fisheries habitat through the removal of bedload material in an historic low flow river channel to create a series of pools and riffles. An estimated 16,000 cubic yards of additional bedload material was to be removed to accommodate the creation of pools for fish habitat.

TCD was responsible for obtaining the required permits, including writing an Environmental Assessment for the Wyoming Bureau of Land Management who has jurisdiction over a portion of the project area, project oversight and administration. The Natural Resources Conservation Service (NRCS) assisted with the field survey. The USACE Planning division provided hydrology, construction oversight, and engineering expertise. USACE Operation & Maintenance division constructed the kicker dike adjacent to the Federal levee in the project area. David Owen of River Springs Partners removed the estimated 54,000 cubic yards of bedload material from the river. Mr. Owen contributed the cost of the removal of the material, screening, and replacement of oversize, estimated at $210,000, as in-kind to the project. Wyoming Game and Fish Department provided fish survey and water quality data on the ponds.

[1] Excavation design attached

CONSTRUCTION

Debris Fences -

Beginning November 1, 1998 the Demonstration Project was initiated with the three phases, main channel excavation, brush/debris fence construction, and pool excavation commencing simultaneously. Elevations and placement of the termination points of each of the five fences were established by U.S. Army Corps of Engineers (USACOE) personnel with the brush/debris fences being completed by Teton County staff near the end of November. The excavation phase of the project was completed by mid-February.

The cost of the fences was considerably higher than the original estimate of $15,000. The final cost was $26,893.75, approximately $12,000 over estimate. It should be noted that the estimates for this phase of the project were very speculative due to the experimental nature of the fences. Given the hands on experience constructing these restoration components on the relatively small scale of the demonstration project, cost estimates for the much larger restoration areas can now be made with a much greater degree of accuracy.

Pools -

Upon an area field survey by USACOE and Wyoming Game & Fish personnel in which the pools were to be excavated, it was decided to reduce the number of pools to be excavated from six, as originally planned from aerial photography, to three. Consideration was given to existing topography, stability of the historic overflow channels and the level of disturbance to vegetation that would be experienced during excavation. A total volume of 6334 cubic yards of material was removed from the three pools. While only one of the pools has any direct contact with the river, groundwater filled each of the pools with the lower pool experiencing enough infiltration that it established a steady outflow of 1-2 cfs. These pools were periodically checked throughout the winter by Wyoming Game & Fish personnel to determine if oxygen levels in the water would be sufficient to support overwintering fish populations.

The site pictured above is of the lower pool at the end of an abandoned channel

Corps of Engineers personnel supervising the excavation of the lower pool

Completed lower pool prior to runoff

While the initial cost of the excavation of the pools was well below estimates, two elements arose that should be considered in future projects of this nature on multi-jurisdictional managed lands. The pools were located on Bureau of Land Management property and therefore the excavated material could not be sold. An arrangement was made with Teton County to stockpile the material at a privately owned quarry in the area in which the County held a lease agreement. The material would then be used in future river restoration or maintenance projects as required. The terms of the agreement and an ongoing legal action required that personnel be placed at the gated entrance to insure that material was only taken into the quarry and not removed. Also, an easement for the haul road had been obtained with the landowner on whose property the road crossed. A condition of the easement was to have personnel placed at a gate on the property to insure that livestock did not pass. The addition of personnel created an unforeseen cost for the excavation.

These "before and after" photos are of the middle pool area. This area is about midway down the secondary overflow channel on the island. The water shown in the left photo appeared during excavation and is being supplied by groundwater percolation. This minimal level was sustained throughout the winter.

Channel Management -

Prior to commencement of the main channel excavation USACOE and District

personnel performed a field survey to establish the specific dimensions of the excavation. Cross sections surveyed at 100 foot intervals, extending from 300′ south of the Wilson bridge to 1200′ north of the bridge, were recorded and will serve as the basis for future monitoring. The initial draft plan for the excavation was based on the desired final dimensions of the finished channel modification and had not taken into account the instability of the material within the channel during spring and summer flows. After review of the field survey it was decided to decrease the surface area of the excavation by approximately one third given the amount of material in the proposed excavation site. New plans were provided to Owen's Excavation Inc. and the excavation was begun.

Channel management activity required additional heavy equipment in the immediate area of the Wilson Bridge. Aggradation of material was so excessive that the riverbed was lowered up to thirteen feet in this area. A small bulldozer was used to push the material out to the backhoe so that it could be loaded into the dump trucks

After the material was removed from under the bridge, the operation moved upstream to some of the larger gravel bars.

To accommodate the special conditions of the 404 permit and to address concerns of the Department of Environmental Quality and the Wyoming Game & Fish Department, the excavation of the channel was accomplished in two phases. The first phase included the installation of a 36″ corrugated metal pipe to accommodate an existing flow in a side channel of approximately 100 cfs that was on the west bank of the river. The placement of the pipe served several purposes. It allowed for dry access to the eastern side of the excavation while allowing for a continued flow through the side channel in case fish were present. Once the pipe was in place the flow was then reduced to approximately 25 cfs by the placement of rock in the upper inlet of the side channel. This measure incrementally dewatered a majority of the side channel thereby insuring all work would take place in the dry, while allowing for a minimum flow necessary (and minimal impact) for any aquatic organisms present.

The process of gradual dewatering one half of the excavation at a time provided a method of extracting bedload material "in the dry" while minimally impacting water quality and existing fish populations.

Work was initiated on the downstream end of the eastern half of the excavation and proceeded to the upstream end. Once the material had been removed down to the desired elevation on the eastern half of the excavation, the streamflow down the western side of the excavation was allowed to flow into the excavated eastern half effectively dewatering the western half. The shifting of the minimum flow was accomplished with little impact to water quality in the main stem of the river. Periodically throughout the duration of the project water quality testing was performed by TCD staff above and below the work site using an EPA approved DH integrated sampler. Sampling methodology included working across a section of the main channel of the river moving the sampler vertically through the water column at 10 foot intervals. The cross section sampled on the downstream end was 100' below the confluence of the main channel of the river and the side channel to provide an appropriate mixing zone. Samples then were sent via Federal Express to the Wyoming State Lab for analysis for Turbidity and Total Suspended Solids. A maximum increase limit of 10 NTU's has been established as a condition of the 404 permit. Results from analysis determined that turbidity did not exceed an increase of more than 1 NTU and suspended solids increased an average of 1-2 mg/l, far below the established thresholds.

After the side channel flow had stabilized in the eastern side of the excavation, work began on the downstream end of the western side. Unfortunately as work began on this section little snow (which inhibits ground frost) had fallen in the area and two weeks of subzero temperatures drove the frost level in the ground down about five feet. This slowed progress considerably and it became apparent that the February 1 stop work order, due to the Bald eagles in the area, would have to be exceeded in order to facilitate placement of the screened oversize cobble (4" and larger) back in the excavated area to provide armoring. After a consultation with Pat Diebert of the U.S. Fish & Wildlife Service, it was agreed to extend the work window primarily due to the location of the permitted year round gravel processing site which was closer to the nests than the extraction site. The excavation was completed with a total of 36,208 cubic yards being removed.

MONITORING

Monitoring of the demonstration project area is a vital component of the overall study of restoration techniques on the Snake River system. Data obtained will be used to make adjustments to the restoration methodology. Once the impacts are more clearly understood and the effectiveness is validated, the tools can then be applied more effectively in the other Study areas along the Snake River. A number of separate monitoring methods are utilized to observe the variety of restoration measures used in the area.

Debris Fences -

The function of the debris fences was to catch floating debris, creating areas of diminished velocity both immediately up and down stream of the fence. In these areas the relatively slow velocities created an area for the sediments suspended in the runoff to drop out and accumulate. As runoff flows recede, this sediment deposition creates a nutrient rich environment in which shrub/scrub vegetative and grass species can establish viable populations quickly. This growth in turn stabilizes the sediment and the soil building process begins. Soon tree species begin to colonize the area which will provide long-term bank stabilization. The fences were built to afford "50 year" protection after which natural growth will provide protection.

To establish sediment gain / loss, elevations were surveyed between the fences both pre and post runoff. These elevations combined with photo points and vegetation transects will provide evidence of both the quantity of sediment captured and rate of vegetative colonization.

Prior to the 1999 runoff event this area was composed primarily of cobble and gravels. Post runoff observations reveal that silts and nutrient rich sediments were deposited.

Pools -

The pools were dug to create fisheries habitat for resting, overwintering, and spawning. Fish population surveys have been completed by Wyoming Game & Fish personnel in this area. These surveys will be repeated in the future and will show any increase in quantity of fish due to the improvements in the area. It will be difficult to justify the changes in population in the area to the pools. Monitoring that directly correlates to the success pool habitat includes recording the rate of sediment accumulation through survey, flow calculations, dissolved oxygen measurements in the winter, and visual observation.

Upper Pool nine months after construction.

Channel Management -

In an attempt to understand the causal effects of bedload movement and erosion with channel and point bar formation several survey tools were used. Through the use of aerial photography the extent and rate of destruction of island habitat in the area has been documented from 1944 to the present. Using recent photography, two foot contours of the area have been plotted to be used as a baseline in order to determine the increase in the total area of the island. Additionally, cross sections of the river at 100 foot intervals from 300′ below the Wilson bridge to 1800′ above the bridge are surveyed during low flows each year. Once analyzed, this data should provide some indication of the effects channel excavation and placement of debris fences have had on channel/point bar geomorphology and hydrology. Photo points were also used to provide a visual record during runoff events.

FINDINGS

Debris Fences -

The primary function of the debris fences was to trap debris thereby facilitating the deposition of sediment. As they meet their primary function the fences act as catalyst for the island creation process that naturally occurs in the Snake River floodplain. This restoration tool can then be used in areas where islands were historically located and to augment the few remaining islands to enlarge them to their historic proportions. Evidence of the success of the fences is indicated in this panorama series of photos.

6/4/99

The upper part of the brush fence area provides solid evidence of its ability to capture silt. The first series was taken at river flows of 15,900 cubic feet per second. Water had first appeared the day before in the fenced area and is "subbing" up e.g. ground water pooling at this point. Note the distance the main channel of the river is from the end of the fences. At low flow the edge of the channel was at least 40 meters out from the fence in this location.

6/25/99

The second series (17,200 cfs) was taken the first day that the site could be accessed after peak runoff (20,600 at 6/18/99). The fenced area has had river flows passing through for about 15 days at this point. Note the heavy current impinging on the end of the fence at left and the main channel of the river moving into the fenced area but being diverting back away by the fences.

7/9/99

Spring runoff flows have receded to 8,800 cfs in this series. Significant deposition of nutrient rich sediment (up to 18" in most areas) has occurred with the fences functioning as expected.

While the debris fences functioned as expected, they also provided an unanticipated level of direct protection to the area. Not intentionally designed to endure a direct impingement from high velocities, up to 15 feet per second in this case, they performed beyond expectation. Prior to runoff the closest edge of the main channel of the river was 40 meters from the fenced area. During runoff the main channel shifted from river right to river left entering the fenced area from the side rather than from upstream. Acting like kicker dikes, the fences kept the main energy of the flow away from the island. While there was some damage to several of the fences, (four of the outer posts (6" well casing) were bent in half) if they had not been in place there is a high probability that the lower one third of the island would have been destroyed.

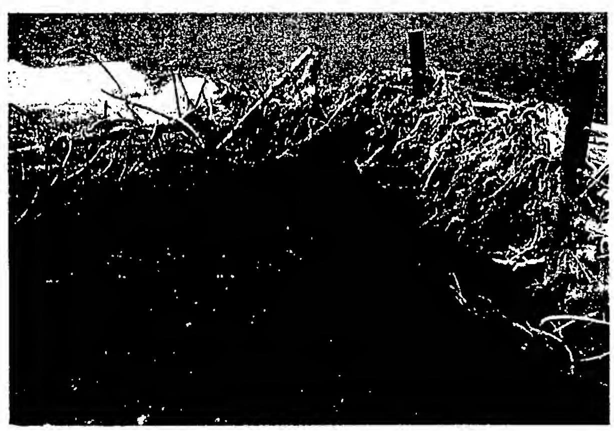
Other debris fence observations of note:

The photo at left illustrates the typical composition of the riverbed in the area of the debris fences prior to runoff. Cobble and gravels constitute the majority with some sand and a little silt. The vegetation is comprised of cool climate grasses and weeds.

This photograph at right, taken June 21st @ 19,600 cfs, shows the fences underwater. The flow at upper end of the fenced area did not have significant velocity, estimated at 2 feet per second. The middle and lower end however experienced high energy impingement, estimated between 10 – 15 feet per second as the main channel avulsed toward the island. You can see the standing waves created by fences three and four near the center of the photo.

Debris fences # three and four at left are acting similar to kicker dikes and deflecting the main energy of the flow (19,000 cfs) away from the island. The hydraulic "head" created by the debris lodged in the fences and impeding flow through the fence and creating "back pressure" was responsible for keeping the flow from entering the area in between the fences.

This is a good representation of the type of material captured by the fences. Note the deep scour hole at the end of the fence. While the end of this fence was damaged from the high flow, the result created excellent fish habitat.



Pools -

Two of the three pools were positioned in an overflow channel that did not receive direct flow from the river for a majority of the year. There was evidence of very high ground water infiltration which would keep water levels in the pools at acceptable levels throughout the year. There was some concern of how well the pools in the overflow channel would stand up to direct flows from the river. The third pool was placed off channel but it was expected that it would fill from groundwater recharge. In summary, all pools performed as expected during the runoff period.

A second concern was how well the pools would support overwintering populations of fish. Wyoming Game & Fish personnel monitored the pH and dissolved oxygen levels throughout the winter. The results, shown below, indicated that the lower and upper pools had favorable water chemistry to support fish, while the middle pool did not. No supported hypothesis has yet been developed to provide an explanation for the low dissolved oxygen levels in the middle pool.

SNAKE RIVER COE DEMONSTRATION PROJECT - AREA 9 PONDS

WATER	DATE	AIR	H20	DO	pH	REMARKS
Lower Pool	12/11/98	26F	42F	7 ppm	None	ICE FREE / CLEAR WATER
	1/12/99	35F	40F	10 ppm	8.2	ICE FREE / CLEAR WATER
	2/16/99	36F	ICE	6 ppm	7.7	2" CRUD ICE / CLEAR WATER
	3/17/99	55F	ICE	7 ppm	7.5	EDGE ICE FREE/CLEAR WATER
	4/14/99	45F	47F	9 ppm	8.7	ICE FREE/CLEAR WATER
	5/14/99	50F	46F	7 ppm	8.7	SAME FLOW
Middle Pool	12/11/98	26F	ICE	8 ppm	7.7	2" ICE / CLEAR WATER
	1/12/99	35F	ICE	2 ppm	7.8	7" ICE / CLEAR WATER
	2/16/99	36F	ICE	3 ppm	8.7	7" ICE / CLEAR WATER
	3/17/99	55F	ICE	11ppm	8.7	6" ICE / CLEAR WATER
	4/14/99	45F	52F	8 ppm	8.3	EDGE ICE FREE/CLEAR WATER
	5/14/99	50F	46F	7 ppm	8.7	WATER FLOW INTO POND
Upper Pool	12/11/98	26F	ICE	8 ppm	7.7	1.5" ICE / CLOUDY WATER
	1/12/99	35F	ICE	9 ppm	8.5	1/2 ICE FREE / CLEAR WATER
	2/16/99	36F	ICE	9 ppm	8	4" CRUD ICE/ CLEAR WATER
	3/17/99	55F	ICE	10ppm	9	4" CRUD ICE / CLEAR WATER
	4/14/99	45F	50F	9 ppm	8	EDGE ICE FREE/CLEAR WATER
	5/14/99	50F	50F	9 ppm	8.9	CLEAR WATER

While the lower pool was transformed by erosion early in the runoff period on the lower end into a back eddy by the main river for several weeks, when the river levels dropped a natural coffer dam formed and an adequate water elevation was retained in the pool. The middle pool's configuration did not change although some deposition of sediment occurred during runoff. While there was no direct inlet to the upper pool, during high water outflow discharge was observed as high as 3 – 4 cfs. There was no turbidity observed in this pool at any time. Please refer to field notes on the following page.

Field Notes

5/29/99 - 18,000 cfs
Overflow channel @ 70 cfs. Pool #1 lower end eroding out.

6/1/99 - 15,000 cfs
Overflow channel @ 5 cfs.

6/7/99 - 15,600 cfs
Overflow channel @ 35 cfs.

6/14/99 – 15,700 cfs
Overflow channel @ 5 cfs but outflow @ 20 cfs indicating significant groundwater infiltration.

6/15/99 - 18,000 cfs
Overflow channel @ 10 cfs, outflow @ 25 cfs. Lower and middle pools have water backing in from the channel at the lower end. Main river channel is avulsing to the east.

6/17/99 - 19,400 cfs
Overflow channel @ 15 cfs. Lower pool filled completely with backwater from river.

6/19/99 - 20,100 cfs
Overflow channel @ 25 cfs.

6/23/99 - 18,900 cfs
Major inflow reduction although outflow from lower pools is down only slightly. Low turbidity indicates

Strong groundwater infiltration. Preliminary observation indicates lower pool did not headcut and lower reach is intact! Observed fish rising in lower pool.

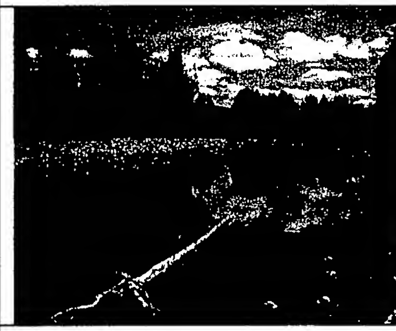
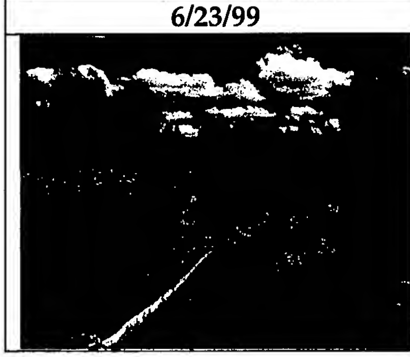
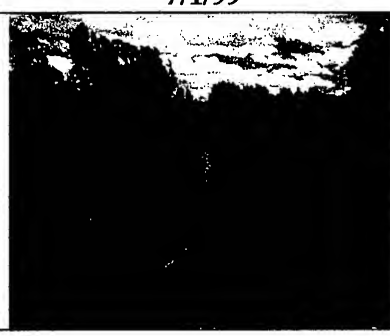
7/1/99 - 9,800 cfs
Inflow absent, good outflow.
Sandbar formed at the mouth of lower pool enhancing water storage.

Lower Pool Study Photos

The middle and upper pools experienced a far lesser degree of change in structure as evidenced in the study photos on the following pages.

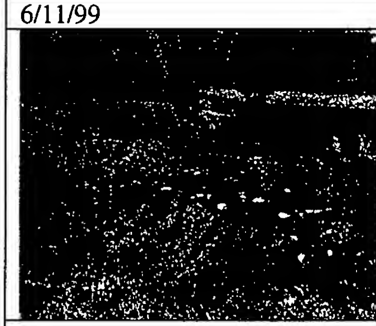
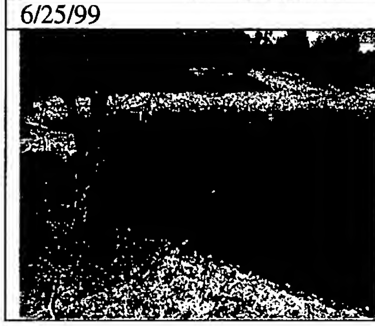
<u>Middle Pool Study Photos</u>

This is the largest pool covering almost one acre. At the far end in the photograph a deep hole was dug as a resting area for fish that is out of the main current. The area in the foreground is much shallower and constitutes the overflow channel floodway.

5/27/99	6/4/99	6/11/99
		
6/23/99	**7/1/99**	**7/13/99**
		

Upper Pool Study Photos

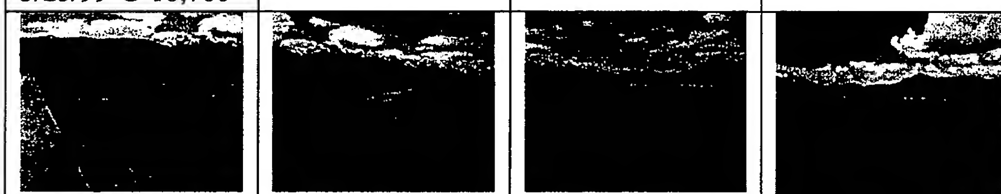
The following three panoramas were taken from different perspectives but are still fairly representative of the upper pool's configuration. In the second series you can see the overland outflow from the pool. While there was no direct inflow into the pool groundwater infiltration supplied a fresh source of water. Currently this pool is being utilized for waterfowl and no fish have been introduced. Wyoming Game & Fish personnel are considering stocking the pool as it has proven to be able to support fish. Additional cover will have to be used to protect the fish from the Osprey and Bald eagles in the area.

5/27/99		
		
6/11/99		
		
6/25/99		
		

Channel Management -

When the islands are restored within the levee system, the river channels must be deepened to accommodate the loss of floodway conveyance created by more surface area. In river restoration efforts, opportunities exist to increase flood capacity while concurrently attempting to stabilize the channel through planned bedload extractions. In the demonstration project area it was desired to have a single channel adjacent to the island and have it split into two channels below[2]. Note in the following photo point record, the main channel established itself as planned. Unfortunately the secondary channel excavation in front of the boat ramp filled back in with bedload material almost immediately upon commencement of runoff. However, even though the channel management activity was not totally successful, a great deal of data was compiled which when analyzed will provide important information on river hydrological and geomorphological processes.

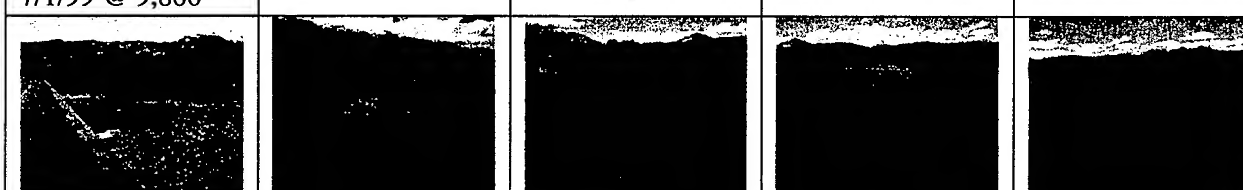
5/25/99 @ 10,700



6/7/99 @ 15,200

6/21/99 @ 19,600

7/1/99 @ 9,800



7/19/99 @ 6,640

The debris fences and pools are located on the island in the background on the right side.

[2] see attached excavation plan

The Good

by Jim Morrison

Restoring riverside habitat damaged by man may require a man-made solution.

From my vantage point, the winding Snake River disappears into the rocky, snow-crusted promontories of the Teton Mountains, a view reminiscent of Ansel Adams' often reproduced 1942 landscape portrait.

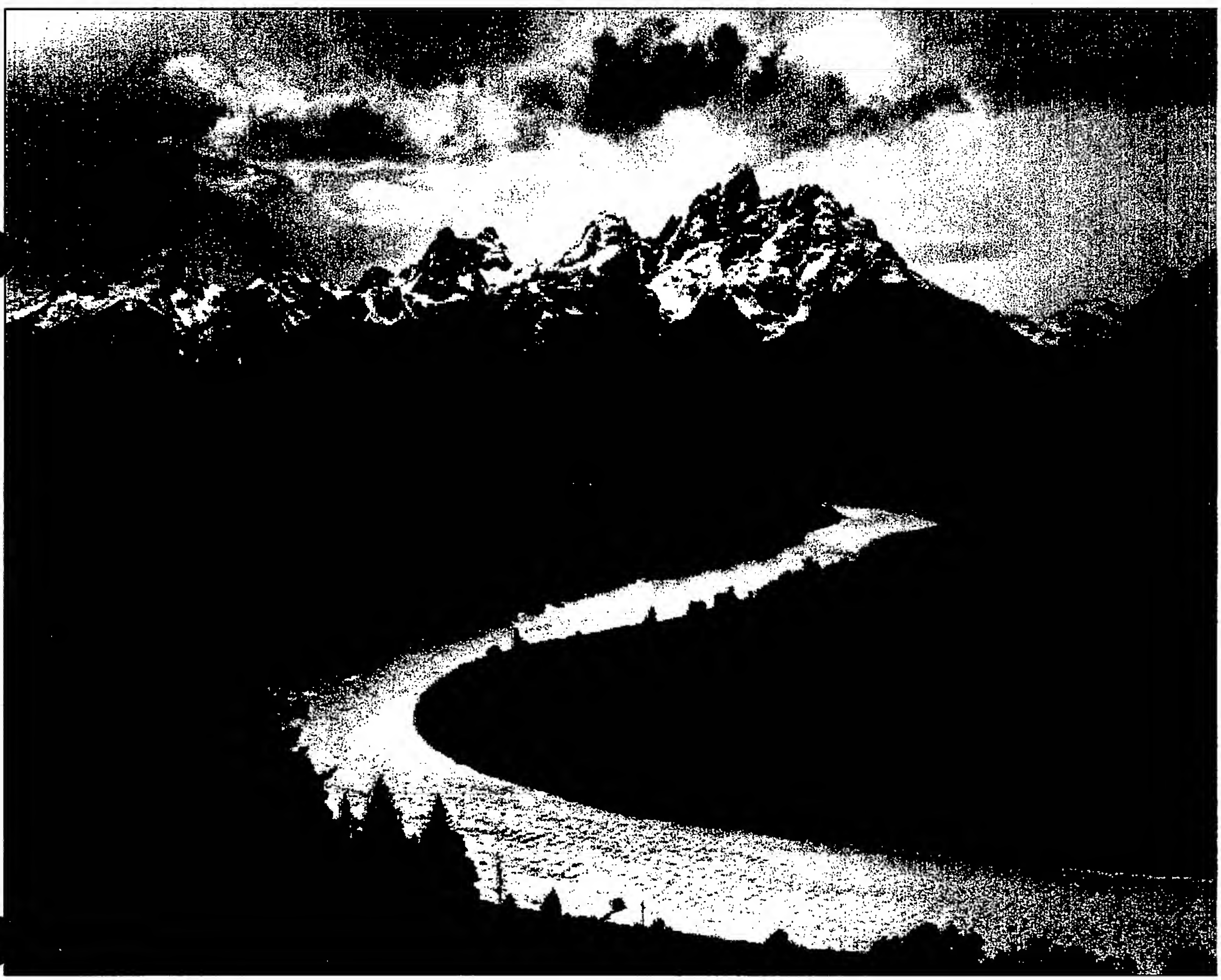
For a first-timer to this remote part of Wyoming, it's a jaw-dropping vista. But it doesn't take Bill MacDonald of the U.S. Army Corps of Engineers long to explain to me that his trained eye sees devastation, not beauty.

"This is the ecological ghetto," he says firmly, pausing along the river, just outside Jackson Hole and south of Grand Teton National Park.

MacDonald, along with Rik Gay of the Teton County Natural Resource District and Pam Lichtman of the Jackson Hole Conservation Alliance, is standing in a dry channel. Behind them rise a stand of mature cottonwood trees and a thicket of scrub willows on what becomes an island annually when melting snow creates a spring torrent. Such islands—a vital habitat—are increasingly rare along this stretch of the Snake River.

When Ansel Adams photographed the Snake River and Teton Mountain Range in 1942, lush vegetation covered the riverbanks.

Flood



Jim Morrison

Barren stretches of white river cobbles along the Snake River have replaced the thick stands of trees seen in Ansel Adams' 1942 photo.

We're here to inspect a unique attempt to help revitalize the river and recreate those islands and grow new stands of trees. Time is short. Rik Gay figures that without action all the islands and small pools along this section of the river will disappear within 20 years, leaving vast, sterile stretches of riverbed cobbles.

The Taming of the Snake

What transformed the lush riverbanks of Adams' portrait into the wasteland of today? The taming of the Snake, specifically 22 miles (35 kilometers) of sinuous rock levees built along here during the 1960s to control floods and protect ranchers' property. Indeed, the levees have saved pastureland and, more recently, lavish homes. But they also have radically altered the ecology, confining what was a wild, braided, multichanneled river and wiping out islands and riparian (riverbank) areas, home to trees, birds, fish, and even moose.

Gone, too, are the seasonal floods that for centuries recharged the river's food chain. Cottonwoods need the spring flood cycle to grow. The few that remain, like those on that island, bear silent witness to another time. Now, barren stretches of whitened river cobbles have replaced the thick stands of trees in Adams' half-century-old photograph.

Lichtman, a hydrologist with the Jackson Hole Conservation Alliance, explains why the trees are disappearing. "Flooding is a disturbance regime," she says. Like fire, it rejuvenates an ecosystem even as it destroys.

In recent years, conservationists have begun to better understand and trumpet the virtues of a river's ebb and flow, its respiration. The realization, of course, is not new. Ancient Egyptians outlawed flood control, recognizing the importance of the Nile River's life-giving deluges.

But on large stretches of rivers like the Snake, the Mississippi, and the Missouri, levees and dams stymie seasonal flooding. So state, federal, and private organizations have begun investigating ways to reverse or mitigate their environmental damage, balancing on the high wire stretched between the needs of humanity and the needs of nature.

Giving Something Back

What was once inconceivable is now being done. Dams in North Carolina, Maine, Vermont, and California have been dismantled in the last 2 years in attempts to renew rivers. In Washington state, the Elwha Dam and its upstream companion, the Glines Canyon Dam,

are scheduled for demolition in a last-ditch attempt to restore salmon and trout runs on the Elwha River (though so far Congress has declined to appropriate the funds). Some breached levees on the Missouri were not rebuilt after the 1993 floods. In Idaho, controversy rampages over whether to remove four dams from the lower Snake River.

The project I'm here to inspect with MacDonald, Lichtman, and Gay on the upper Snake River, about 50 miles (80 kilometers) south of Yellowstone National Park, is less controversial. It won't require the demolition of dams or leveling of levees, but conservation officials say their unusual technique will make this area look more like the river in Adams' photograph.

Part of the solution being implemented is what MacDonald calls "BioFences." Yes, fences rising from the dry river bottom—as incongruous a sight as the monolith on the moon in the movie *2001: A Space Odyssey*. They were created by pounding well casings 17 feet (5 meters) down into a dry channel, then stringing heavy steel cable and what ranchers in these parts call "cattle panels"—sections of fence used to create temporary corrals.

Gay and MacDonald say the fences will corral debris like branches and logs in an attempt to slow the rushing spring waters and cause sediment to drop, preserving and perhaps even enlarging that endangered island. In a few years, willows—followed by cottonwoods—should take root in the soft sediment. If the BioFences work, MacDonald says they will be used on other swift flowing portions of the river.

In addition to the fences, Gay supervised the dredging of three small pools just off the winter channels that he hopes will serve as spawning pools for the local cutthroat trout.

The fences and the dredging are not elegant solutions to the habitat loss. But, for now, they're the only options. "Removing the levees, that would really be the only way to get it totally natural," says Les Cunningham, a corps hydrologist also along on the tour. "That probably is not politically acceptable." Not acceptable to ranchers, the owners of million-dollar estates that have sprung up along the river, or residents of the nearby town of Wilson, which would have been washed away without the restraining levees.

Gay, who moved to the area in 1984, has canoed, kayaked, and rafted the river often in the last 15 years and watched it change dramatically as the islands with trees began to disappear. "We can't remove the influence we've already exerted on this river. It's not reasonable to think that we could," says Gay. "But it's our responsibility to do something. We need to be able to give something back to this river."

Lessons Learned

"Ten thousand river commissions, with the mines of the world at their back, cannot tame that lawless stream, cannot curb it or confine it, cannot say to it, 'Go here or go there,' and make it obey; cannot save a shore which it has sentenced; cannot bar its path with an obstruction which it will not tear down, dance over and laugh at."

—Mark Twain, 1882

Twain's admiration was for the power of his beloved Mississippi River. More than a century later, the floods of recent years show how little has changed, despite billions of dollars spent constructing levees and dams. The Mississippi and the Missouri floods of 1993 wiped out farmlands and even some small towns.

For people accustomed to living in the floodplain, the floods were a bitter, painful

reminder of a river's unforgiving strength. Property damage in 1993 alone was estimated at $12 billion, while the government spent more than $5 billion for disaster relief.

For the rivers, though, those floods were "normal" respiration, replays of an ebb and flow going back before recorded time. For scientists, the floods were another piece in a puzzle that has become increasingly clear: healthy rivers periodically need to spill into their floodplains.

"There's no question that there's [now] a much better understanding of the role that floods play in the health of rivers than there was before the great flood of 1993," says Scott Faber, a floodplain expert with American Rivers, a nonprofit organization dedicated to saving rivers.

In the West, rivers like the Snake, the Missouri, and the Mississippi are huge vacuum cleaners, collecting trees and leaves and other debris and pulling them into the main channel of the river. There, that debris breaks down and becomes the primary food source for aquatic life. Studies also indicate that fall and spring migrations of waterfowl are timed to flooding because of the feeding.

Scientists have discovered that dams and levees confound organisms adapted to the historical rhythms of rivers. For instance, dams trap sediment and organic debris that would flow downstream. Levees, meanwhile, confine the energy of a rushing river between two walls. The rechanneled water wipes out island and riverbank vegetation faster than it can regrow and prevents the creation of side channels, pools, and wetlands vital to fish, birds, and trees.

"When you wall off a river from a floodplain, it's as if you were closing up all of the McDonald's in the neighborhood, eliminating all of the access a river needs to its food supply," says Faber.

Catfish, trout, and other native species also need to migrate out of the main channel to reproduce. When those side channels don't exist because of dams or levees, the fish have nowhere to go for their amorous adventures.

"A flooded floodplain is the drive-in movie equivalent in the fish world," says Faber. "The lack of flooding is one of the reasons many species in the Missouri and Mississippi are suffering decline."

While farmers and residents spent the aftermath of the 1993 floods trying to rebuild their businesses and homes, biologists fanned out on stretches of the Missouri River to measure how the flood affected the ecosystem. Some counted the vegetation in a 20- by 40-inch (50- by 101-centimeter) plot. Others watched birds, noting their eating habits and activity. Still others dragged nets in the river, trying to snare fish larvae. In all, more than 30 field technicians and researchers from state and federal agencies spent 5 years in tedious research to determine the effects of the big flood. The scientists found the flood dramatically recharged the river's life.

They also acknowledged, however, the difficulty of making today's Missouri resemble the teeming-with-life "Big Muddy" that captivated Lewis and Clark in 1804. Less than 20 percent of the river's vast floodplain in Missouri is amenable to restoration, scientists wrote in a September 1998 article published in *BioScience*. What they proposed was the creation of a "string of beads" along the river by acquiring and rehabilitating key patches of habitat. The idea is that not all the floodplain needs to be opened to flooding to revitalize the river.

Doug Helmers of the Missouri office of the Natural Resources Conservation Service coordinated the 5-year study on the ecological effects of the 1993 flood. Helmers is optimistic

At right: BioFences built on the Snake River are designed to trap silt and debris, helping to enlarge and preserve the river's islands.

Below: Bill MacDonald of the U.S. Army Corps of Engineers talks about the river's ecosystem with Pam Lichtman, a hydrologist with the Jackson Hole Conservation Alliance. In the background loom the snowy caps of the Teton Mountain Range.

both photos by Jim Morrison

the beads concept can strike a balance between the needs of agriculture and the needs of nature.

"I'm not sure that we're going to be able to completely restore an entire ecosystem," he adds. "I think what it will do is at least maintain some of the biological integrity of the system and maybe even bring back some of the historic habitat types that occurred along the river"—habitats like cottonwood and willow forests and the side channels fish use for spawning.

A Shift in Attitudes

Faber of American Rivers is realistic about what is driving the first baby steps toward restoring some rivers by removing dams and levees. "I think the biggest factor is the recognition of the real risk of floodplain development."

Because the building of dams and levees encouraged floodplain development, flood damage has actually grown this century. The United States spends more than $4 billion annually for disaster recovery due to floods.

Paying that bill forced federal agencies to reexamine their polices. For the first time, claims Faber, the United States is spending more money to move people out of harm's way than it

Jim Morrison

Pools like this one have formed near the river, thanks to the rehabilitation projects. One day, fish may use it as a spawning ground.

is to maintain dams and levees. After the 1993 floods, several small towns, including Valmeyer, IL, took federal assistance to relocate on higher ground rather than rebuild in the floodplain.

Most dramatic is the shift by the Army Corps of Engineers, which has spent seven decades trying to control Mother Nature. The corps set aside $25 million last year and a total of $325 million over 6 years for what it calls "nonstructural flood control projects"—voluntary relocation of people living in floodplains and land acquisition.

Still, broad ecosystem solutions are difficult. For most of this century, levees and dams have encouraged settlement in floodplains. Few towns and cities protected by levees are likely to move. Spring floods could make it impossible to drain fields in time for planting some years, an additional hardship on already hard-pressed farmers.

So small steps are being taken instead. Conservation groups and the government are restoring riparian habitat a few thousand acres at a time. For instance, levees along a 2,600-acre (1,040-hectare) section of the Iowa River, overtopped 18 times in 66 years, weren't repaired after the 1993 flood when farmers decided to sell out to the National Fish and Wildlife Foundation (NFWF), a 15-year-old nonprofit organization partially funded by Congress.

The NFWF is working with the U.S. Fish and Wildlife Service and the Department of Agriculture to buy thousands of acres of agricultural land along the Mississippi, Iowa, and Missouri rivers and return them to wetlands.

"Changing the way flood control is done is a huge step toward improving river health in the United States," says Moira McDonald, the NFWF's director of wetlands and private lands initiative.

Each dam or levee removal is bound to be a battle. But McDonald says using flood control dollars to purchase land and allow nature's flood control—wetlands and uninhabited floodplains—to take hold ultimately will save money and preserve the environment. "We continue to pass really destructive flood control projects [like levee building], particularly in the South, but in other parts of the country we're seeing examples of flood control projects that will have long-term environmental benefits," she adds. "I'm optimistic."

A Man-made Solution for a Man-made Problem

On the Snake River, Bill MacDonald is talking about changing attitudes. The levees, he notes, were conceived nearly 40 years ago. "It was a different mentality then," he says. "[The thinking was] we've got to conquer nature and provide a living for ranchers up against the short season and the severe weather."

His comment reminds me of something I'd read a few days earlier in a story about dam building. It quoted from a 1965 Bureau of Reclamation booklet that encapsulated the prevailing mood of the times: "Man serves God. But Nature serves Man."

MacDonald is confident man's latest intrusion into nature's wondrous ways will work on the Snake. "Man has designed levees for flood protection. Now, we're going that much further to protect and restore the natural environment," he says.

The final decision rests with Teton County and the Natural Resource District. Rik Gay figures construction of the fences on four sites, each between 1 and 2 miles (1.6 and 3 kilometers) long, will cost about $5 million, and restoring the islands will be a 50-year job. But that's what he recommended this past fall after watching the fences and pools during the spring floods.

Last year was what researchers call a high flow year on the upper Snake. The BioFences, says Gay, got hammered as the snow melt raced down the river. Four of the 70 well casings, ones near the center where the river forged a new channel, were folded over by the force. But the fences worked. They saved a portion of the island and gathered about 18 inches (46 centimeters) of silt where new growth soon emerged—only to die during the summer drought.

"You could tell from current upstream we would have lost another third of the island if the fences hadn't been there," says Gay. "We didn't expect them to deflect the main current. But, they did. So we got a bonus out of it."

Ideally, about 50 sites along the Snake River would get the fences and have pools dredged, but Gay says he doubts Congress will appropriate the funds.

Creating more man-made intrusions—even if it's to restore the river—rankles Pam Lichtman of the Jackson Hole Conservation Alliance. She is resigned to the political realities restricting restoration. She knows the levees won't come down. Still, she worries about the effects of further tampering with nature.

In her opinion, the ecosystem decline on the Snake began because man tried to manage the river. Now, the corps and local officials are saying the way to repair the resulting damage is to micromanage the river.

"I'm the first one who hopes this works," Lichtman tells MacDonald. "But sometimes I wonder... what we get messing around with the river."

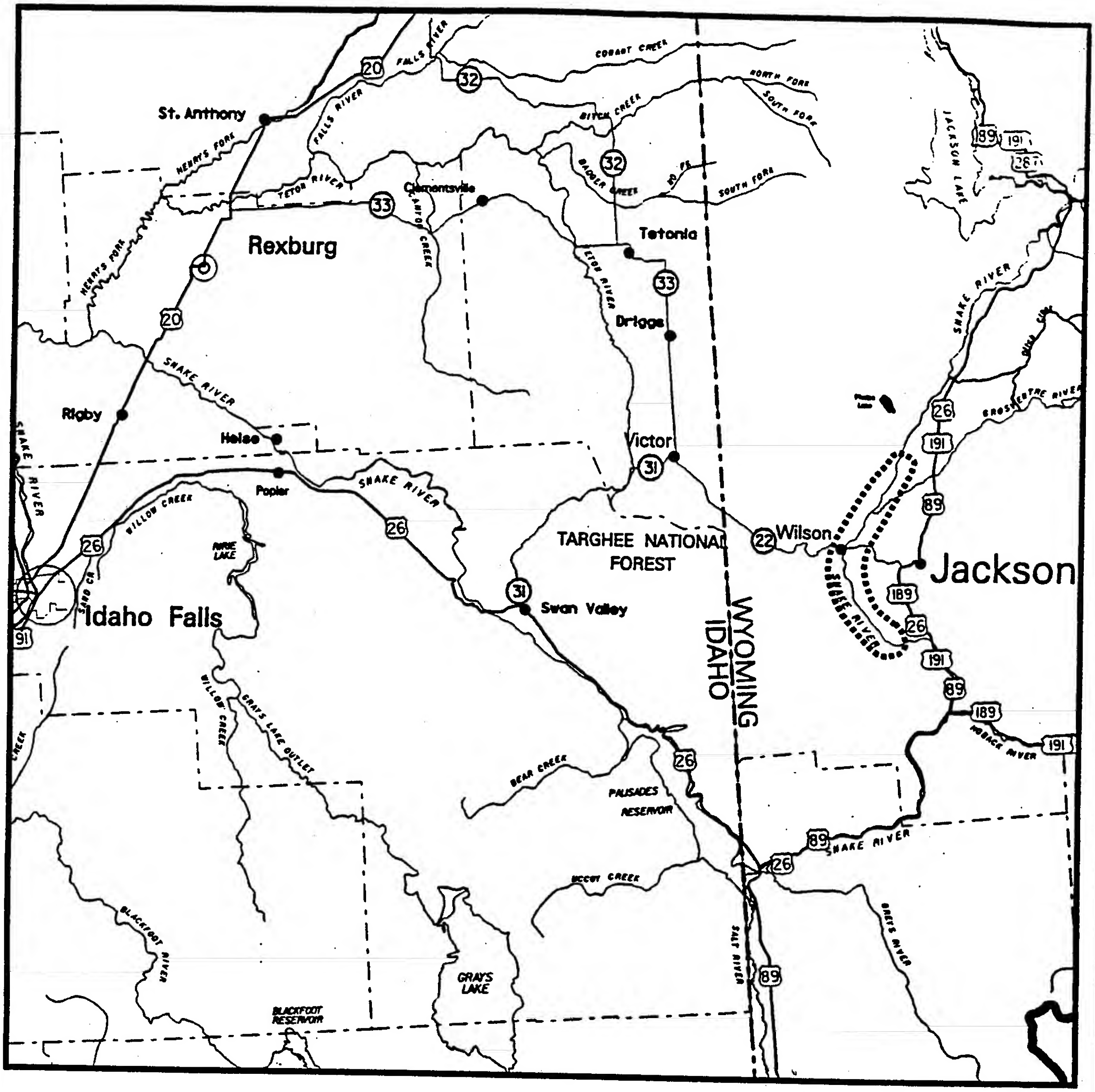
The next morning, with the sun peaking over the horizon, I drive north from Jackson Hole and into Grand Teton National Park. To the west, the Tetons are dusted with snow, though the season's first storm hasn't blanketed the sagebrush of the high prairie.

I pull into a lookout and walk to the edge. Below, the river bends, its banks obscured by thick stands of pines and cottonwoods.

No levees were built this far upriver. The view is as striking as an original Ansel Adams print. And just as rare. CA

Jim Morrison is a frequent contributor to *Compressed Air*, and his work also appears in *Smithsonian, The New York Times, George,* and *This Old House.*

PLATES

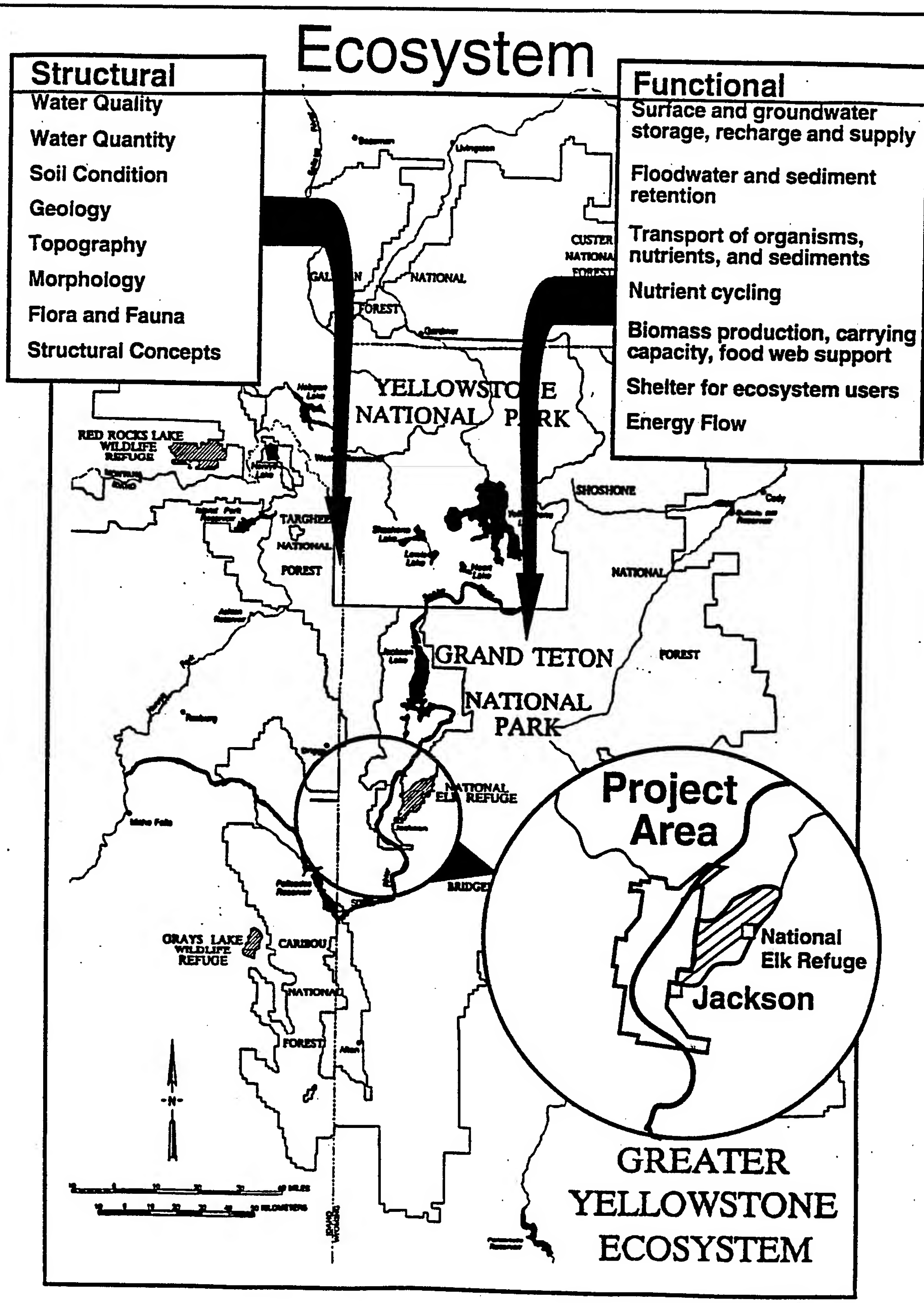


PROJECT LOCATION

Jackson Hole, Wyoming
Environmental Restoration Study
December 1999

Plate 1:
Vicinity Map

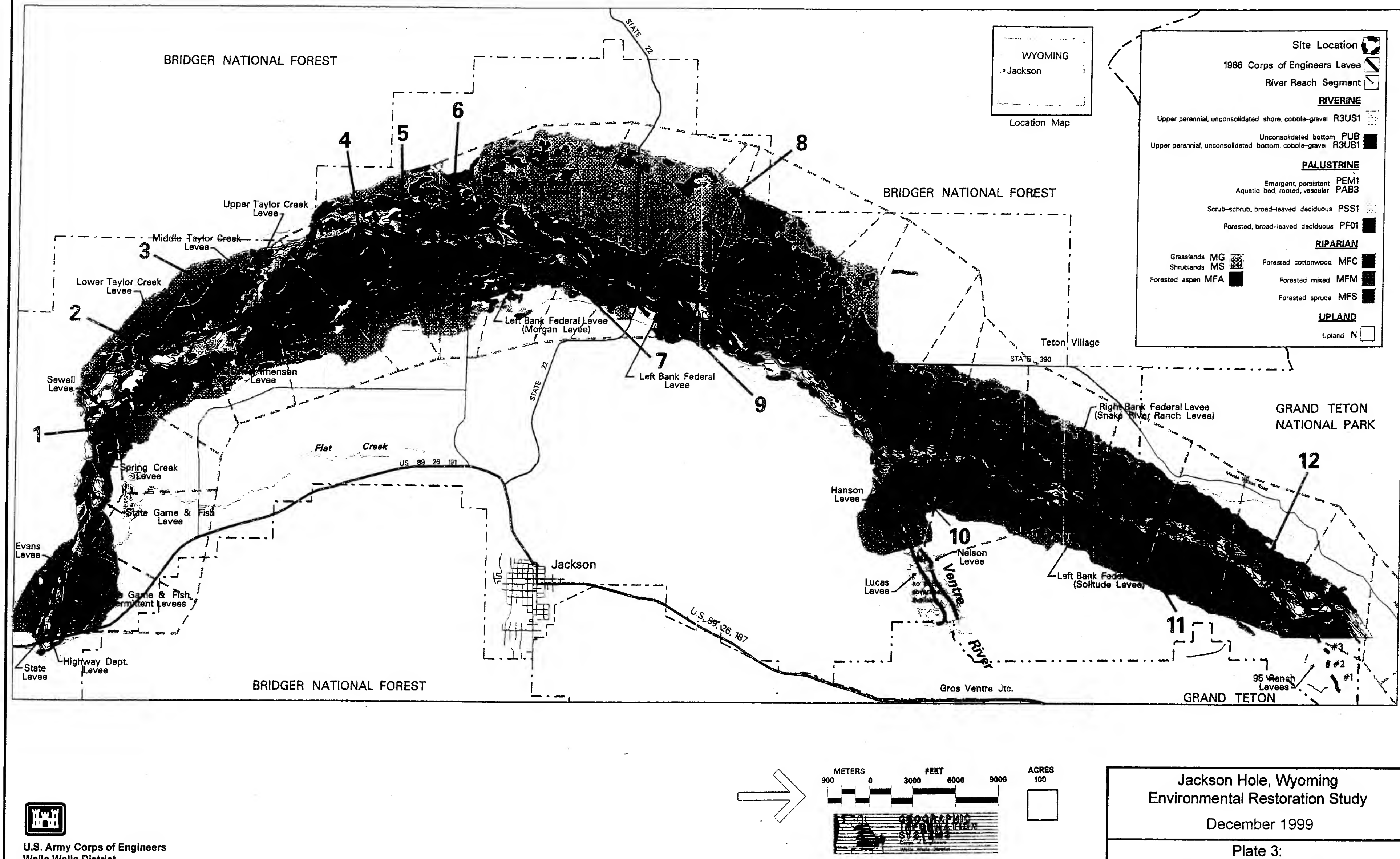
U.S. Army Corps of Engineers
Walla Walla District



Jackson Hole, Wyoming
Environmental Restoration Study
December 1999

Plate 2:
Project Location Map

U.S. Army Corps of Engineers
Walla Walla District

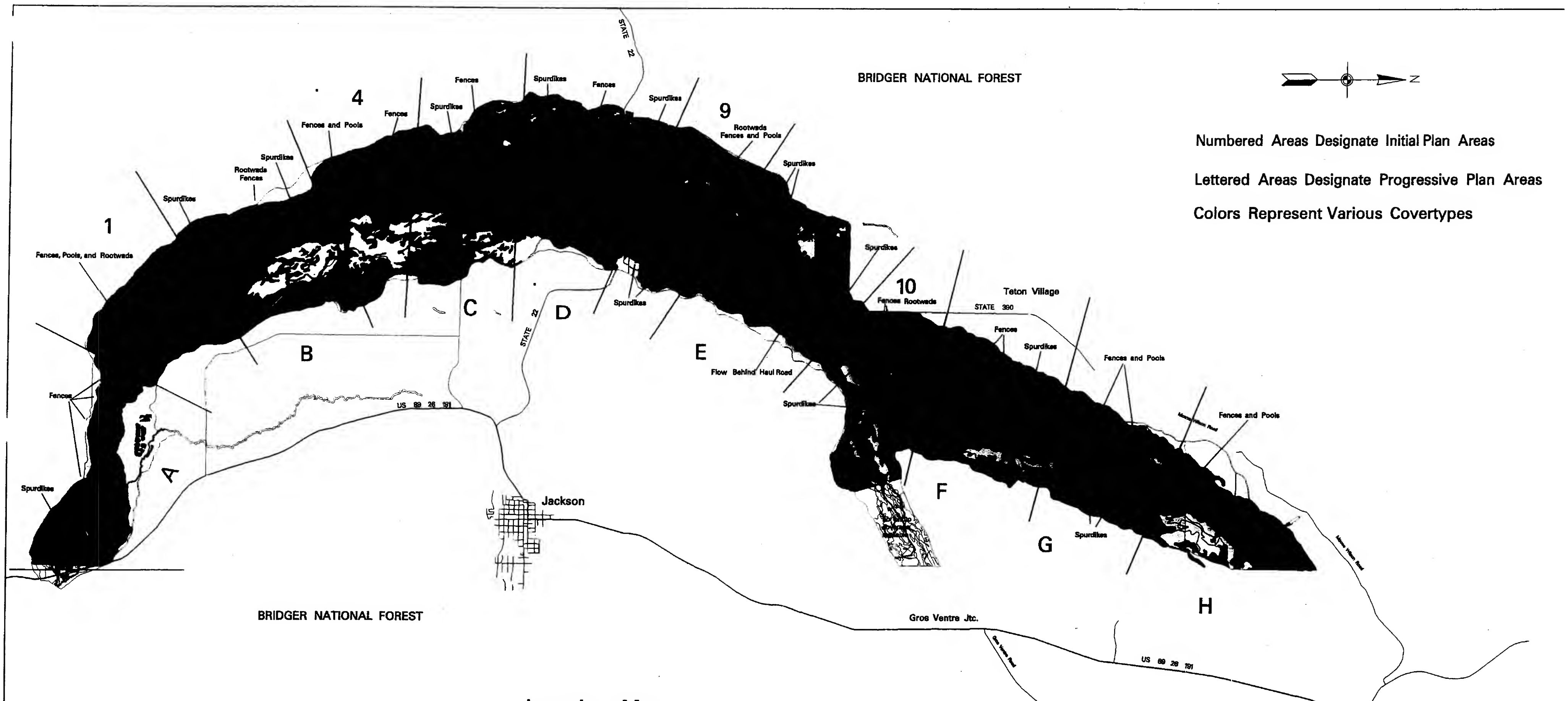


U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study

December 1999

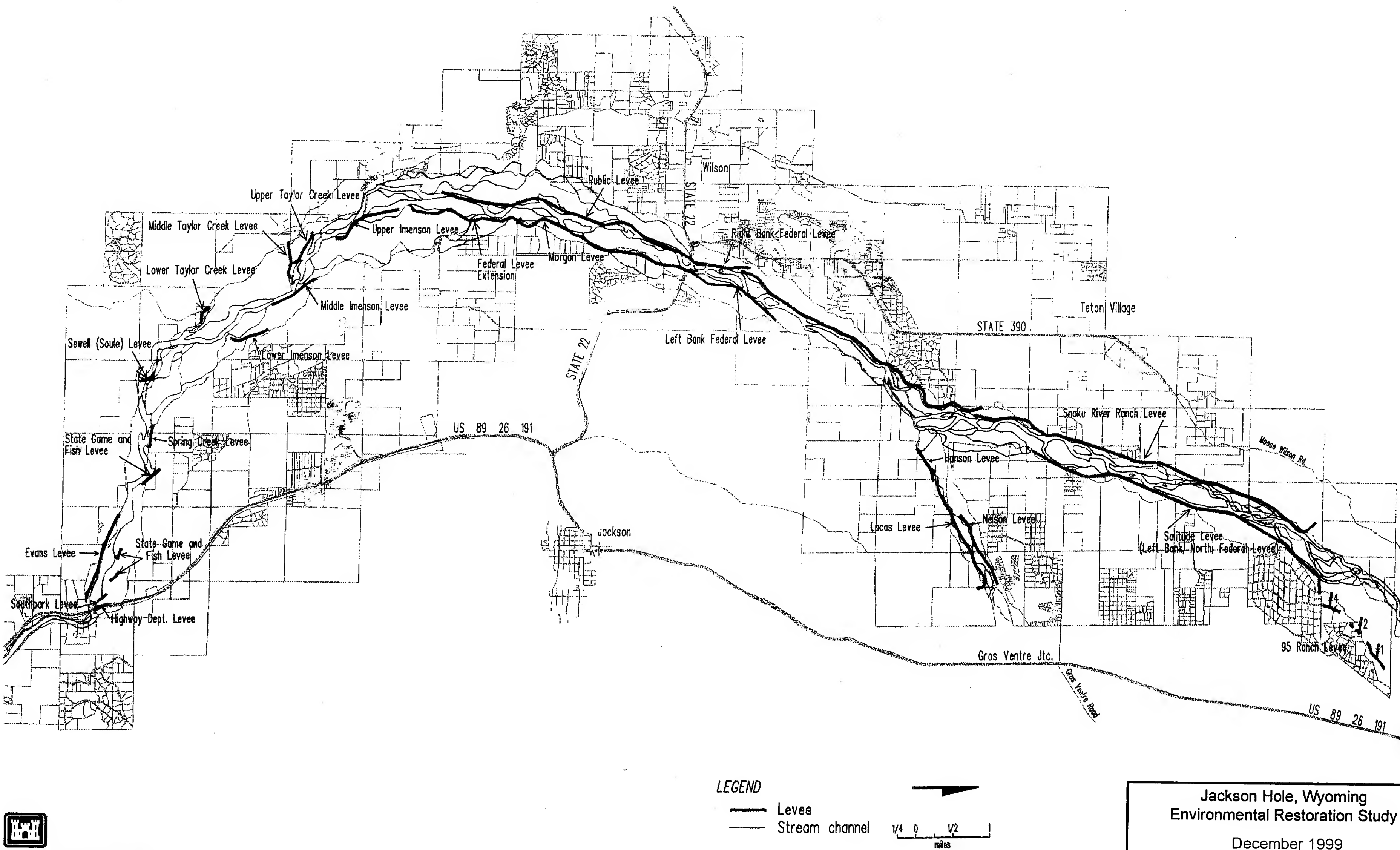
Plate 3:
12 Reconnaissance Sites



US Army Corps
of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study
March 2000

Plate 4
Initial and Progressive Plan Areas

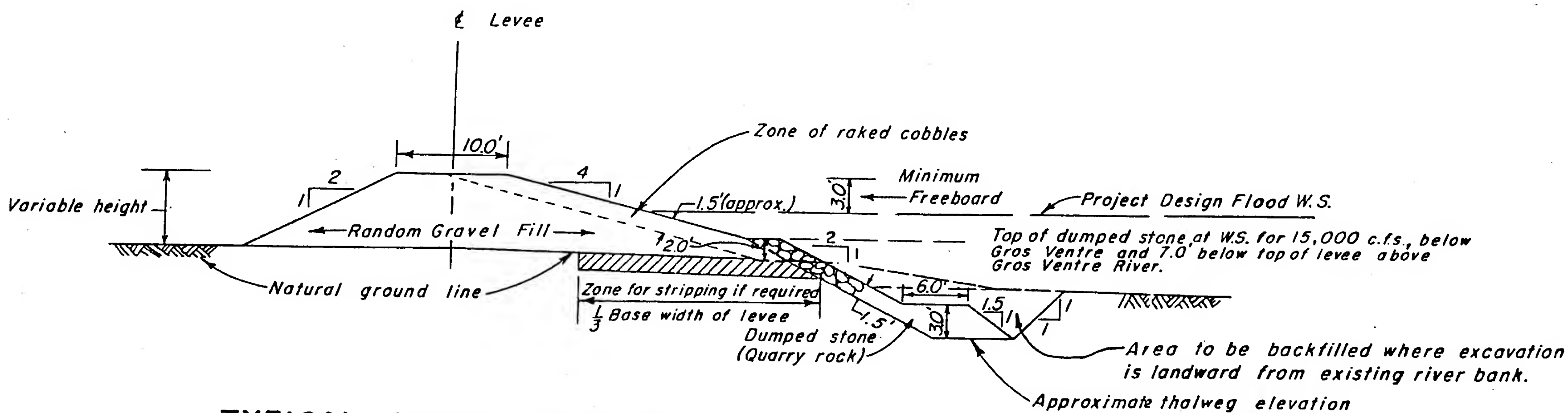


U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study

December 1999

Plate 5:
Existing Levees

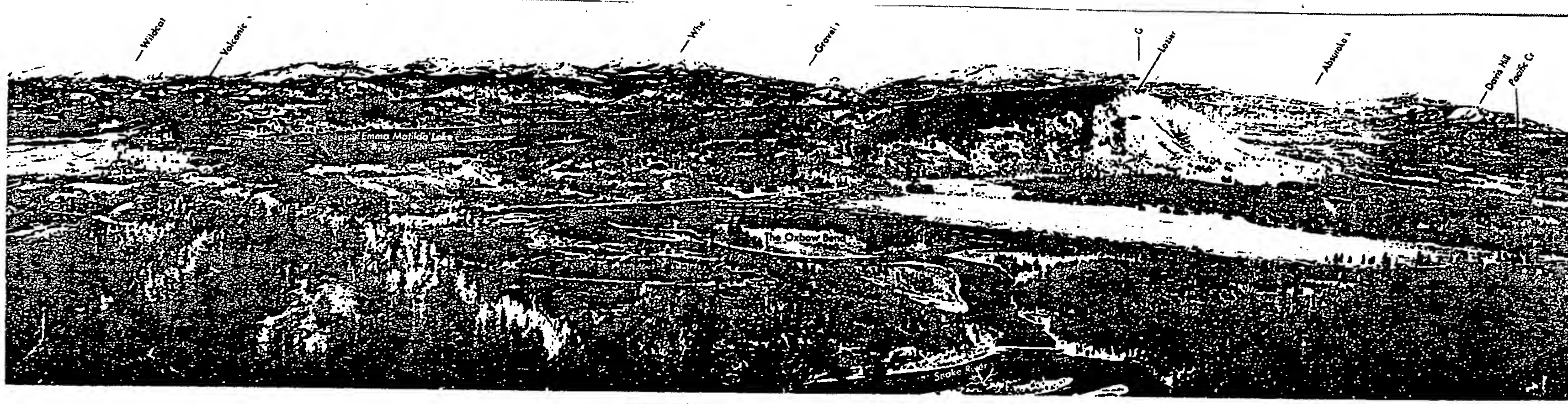


TYPICAL LEVEE SECTION

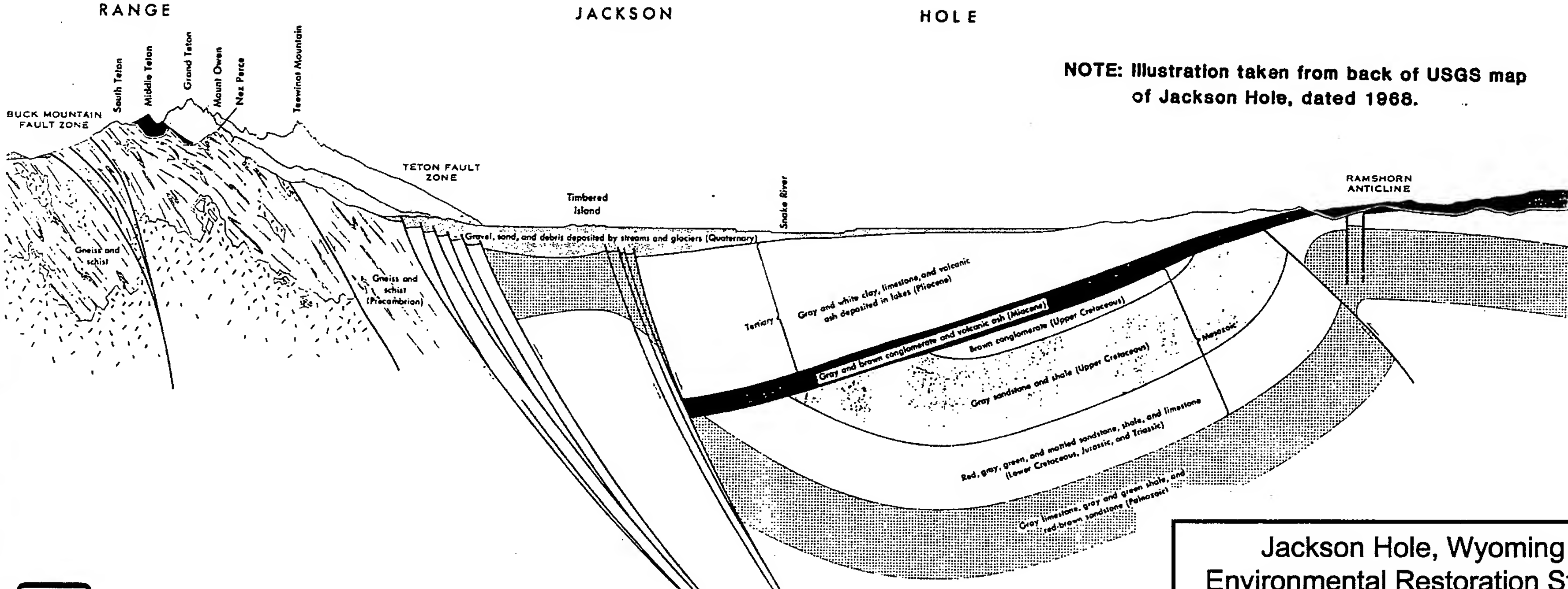
U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study
December 1999

Plate 6:
Typical Levee Section



VIEW NORTHEAST FROM SUMMIT OF SIGNAL MOUNTAIN
Emma Matilda Lake is ponded behind glacial moraines. Most of the peaks and ridges are underlain by sedimentary rocks of Mesozoic and Tertiary age. Position of volcanic vent near Two Ocean Lake is indicated.

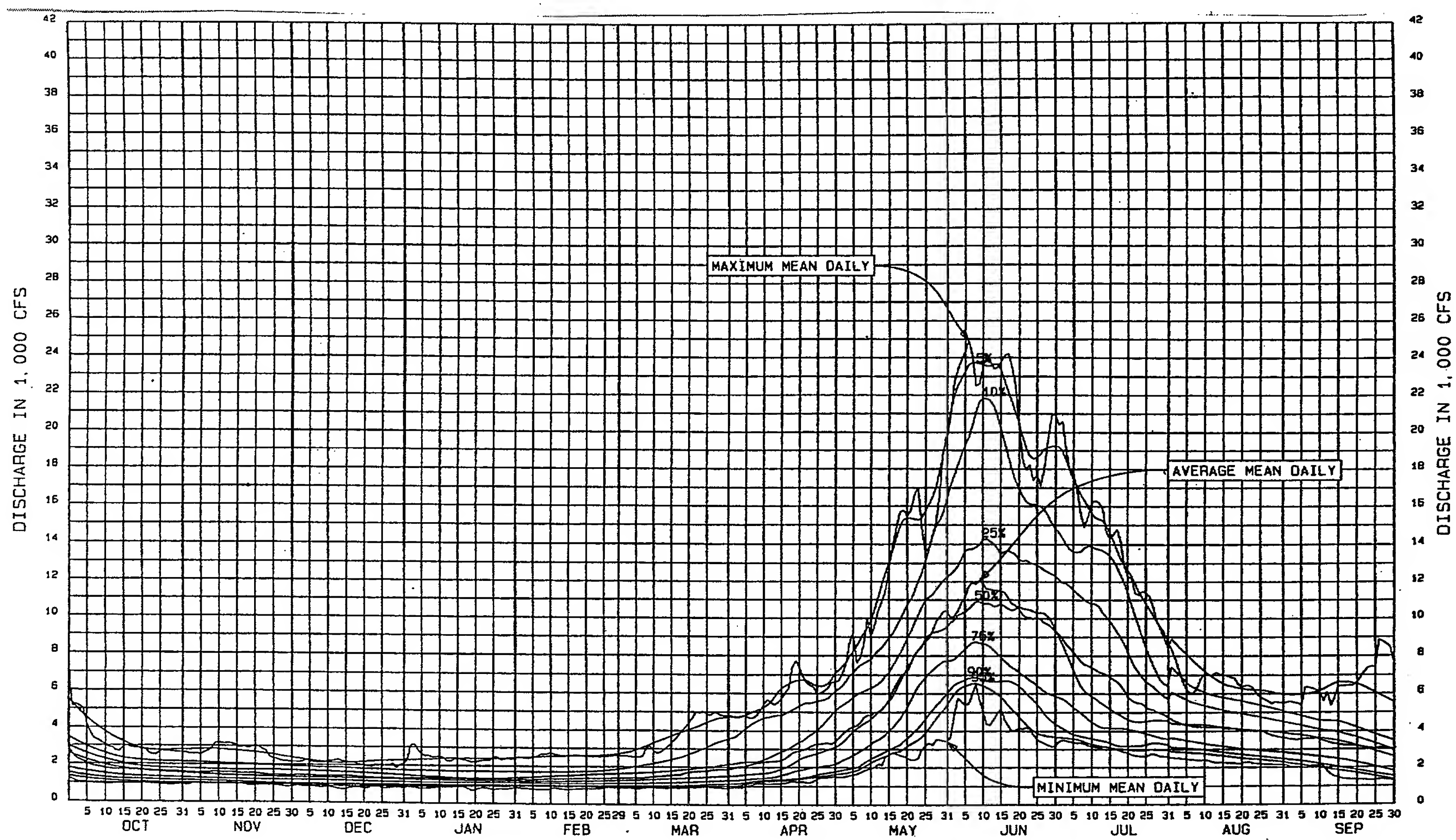


NOTE: Illustration taken from back of USGS map of Jackson Hole, dated 1968.

U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study
December 1999

Plate 7:
Teton Fault Block Tilting



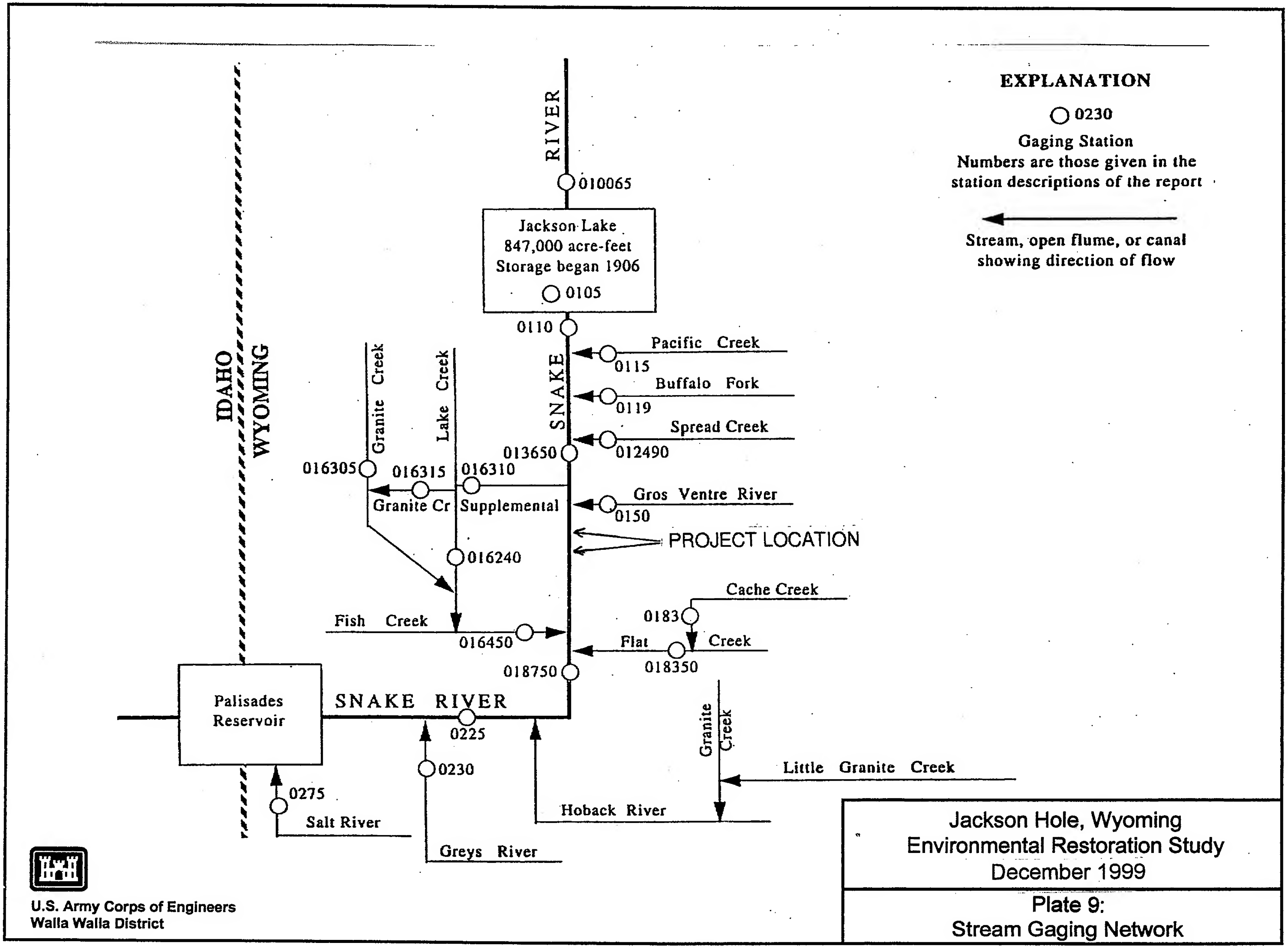
NOTE:

1. PERIOD OF RECORD IS DEC 1975 THROUGH MAY 1997

U.S. Army Corps of Engineers
Walla Walla District

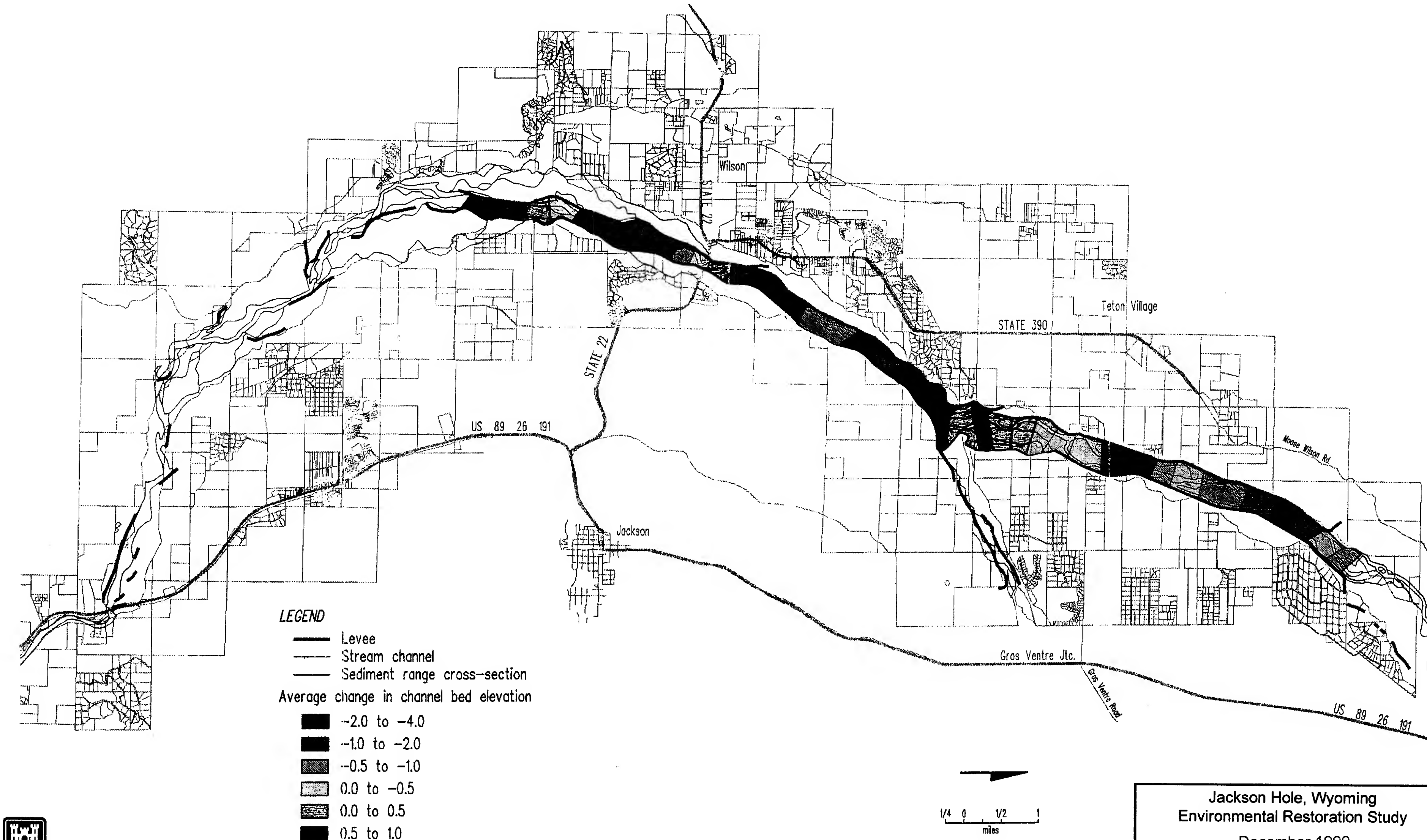
Jackson Hole, Wyoming
Environmental Restoration Study
December 1999

Plate 8:
Summary Hydrographs



Jackson Hole, Wyoming
Environmental Restoration Study
December 1999

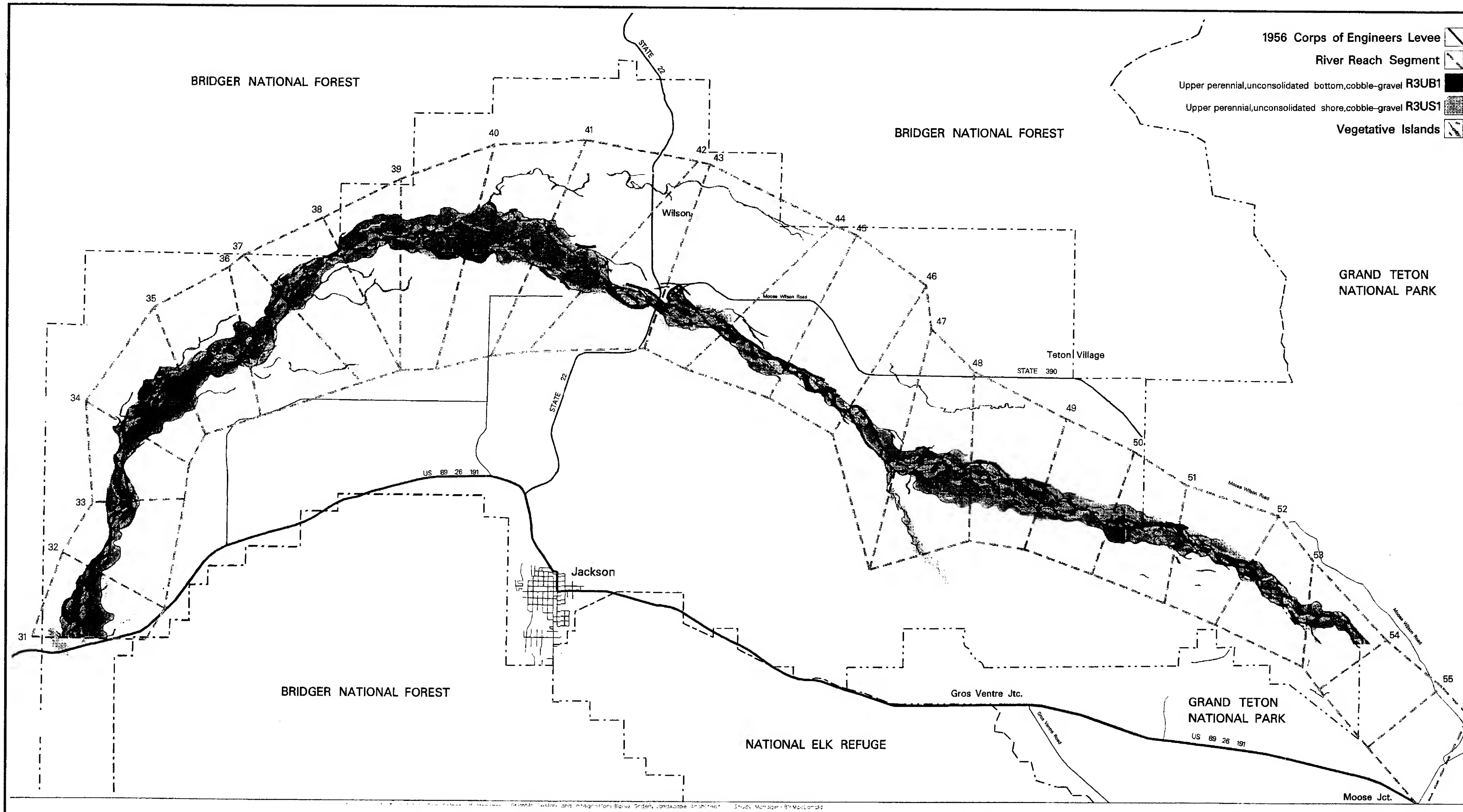
Plate 9:
Stream Gaging Network



U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study
December 1999

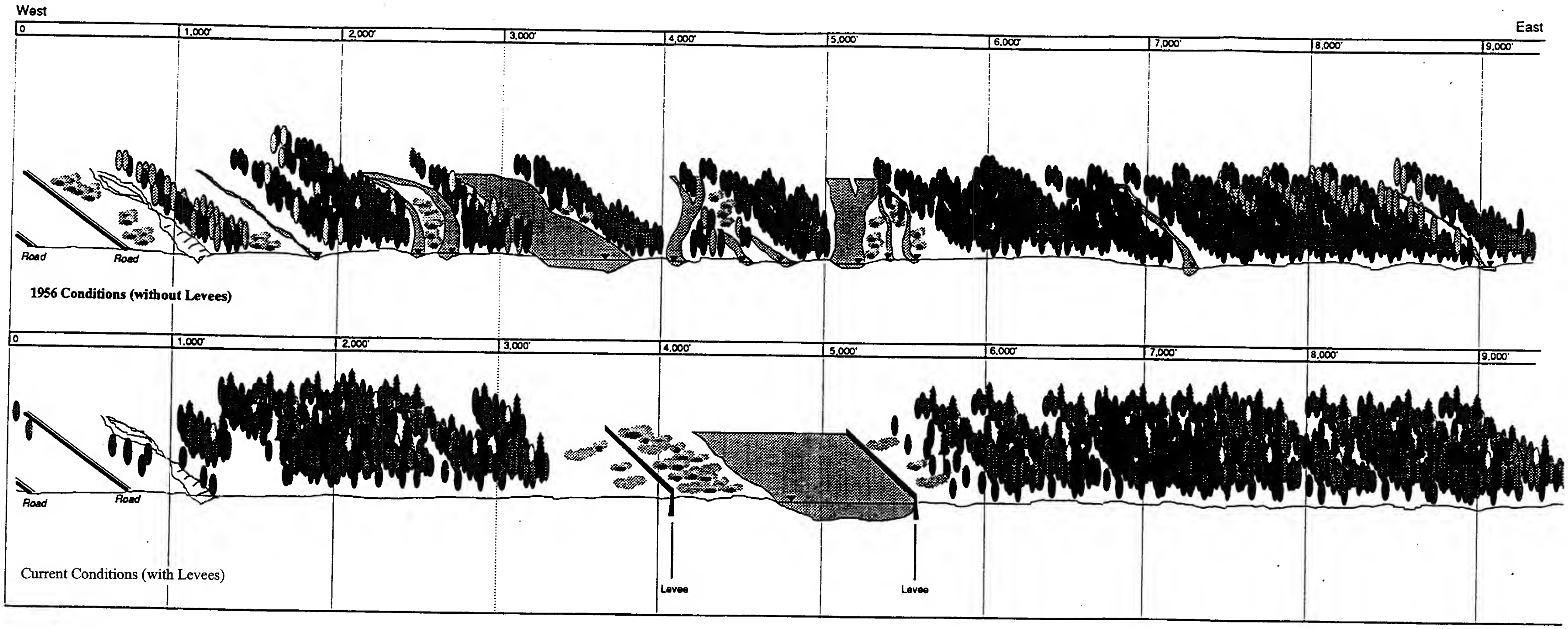
Plate 10:
Average Erosion or Deposition, 1954-1988



U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study
December 1999

Plate 11:
Main Channel Hydrology, 1956

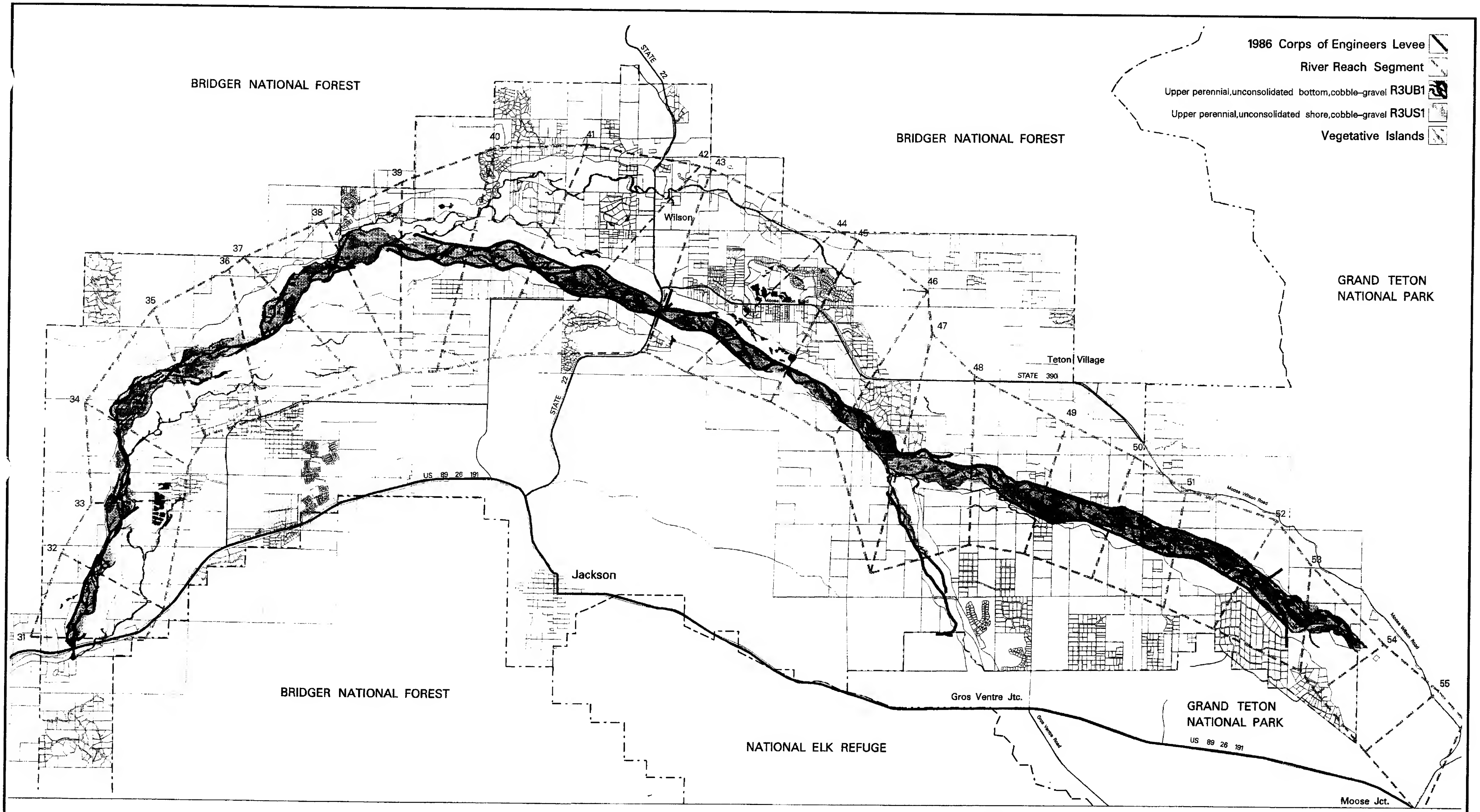


U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study

December 1999

Plate 12:
Snake River Cross Sections, 1956 & 1986

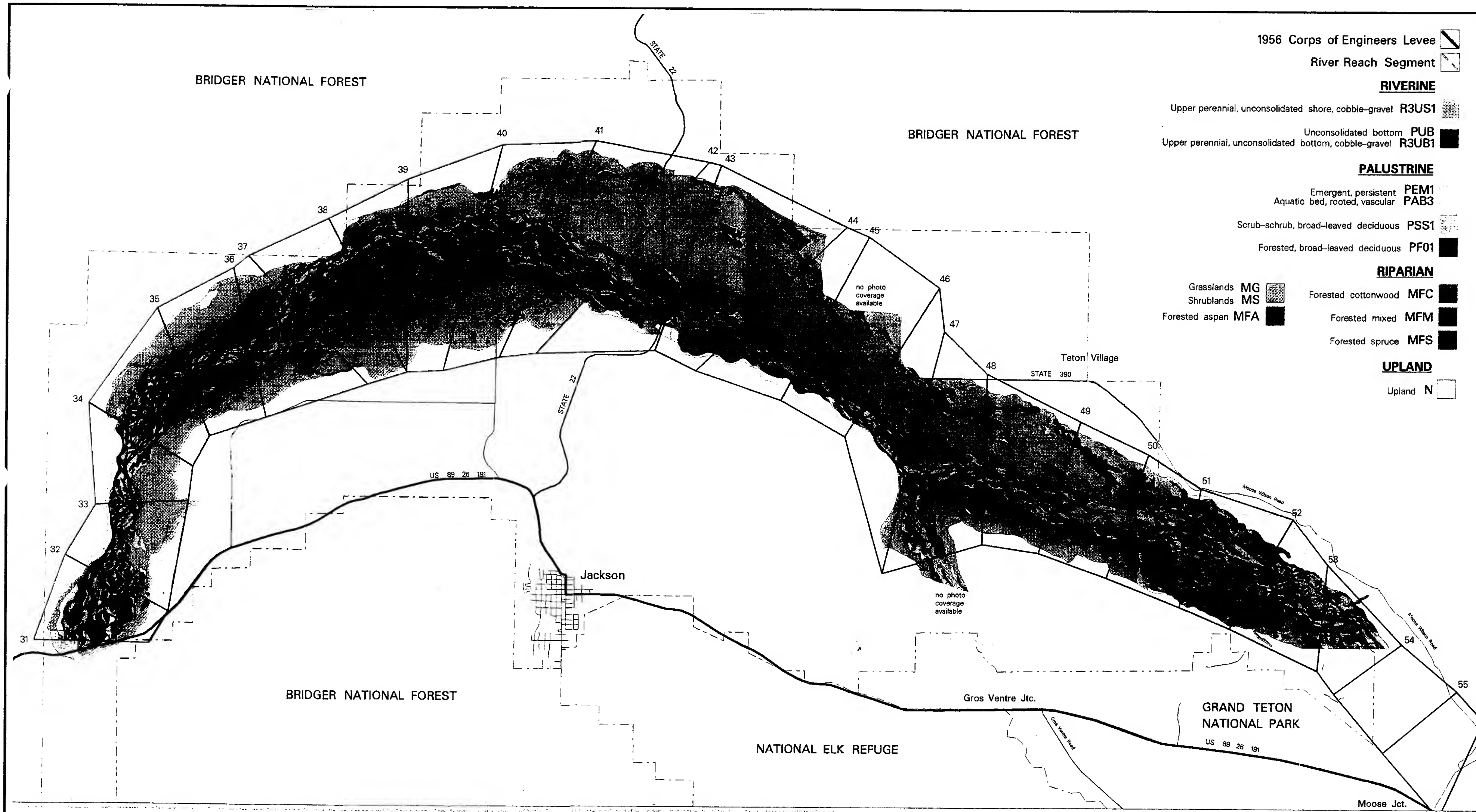


Jackson Hole, Wyoming
Environmental Restoration Study

December 1999

Plate 13:
Main Channel Hydrology, 1986

U.S. Army Corps of Engineers
Walla Walla District

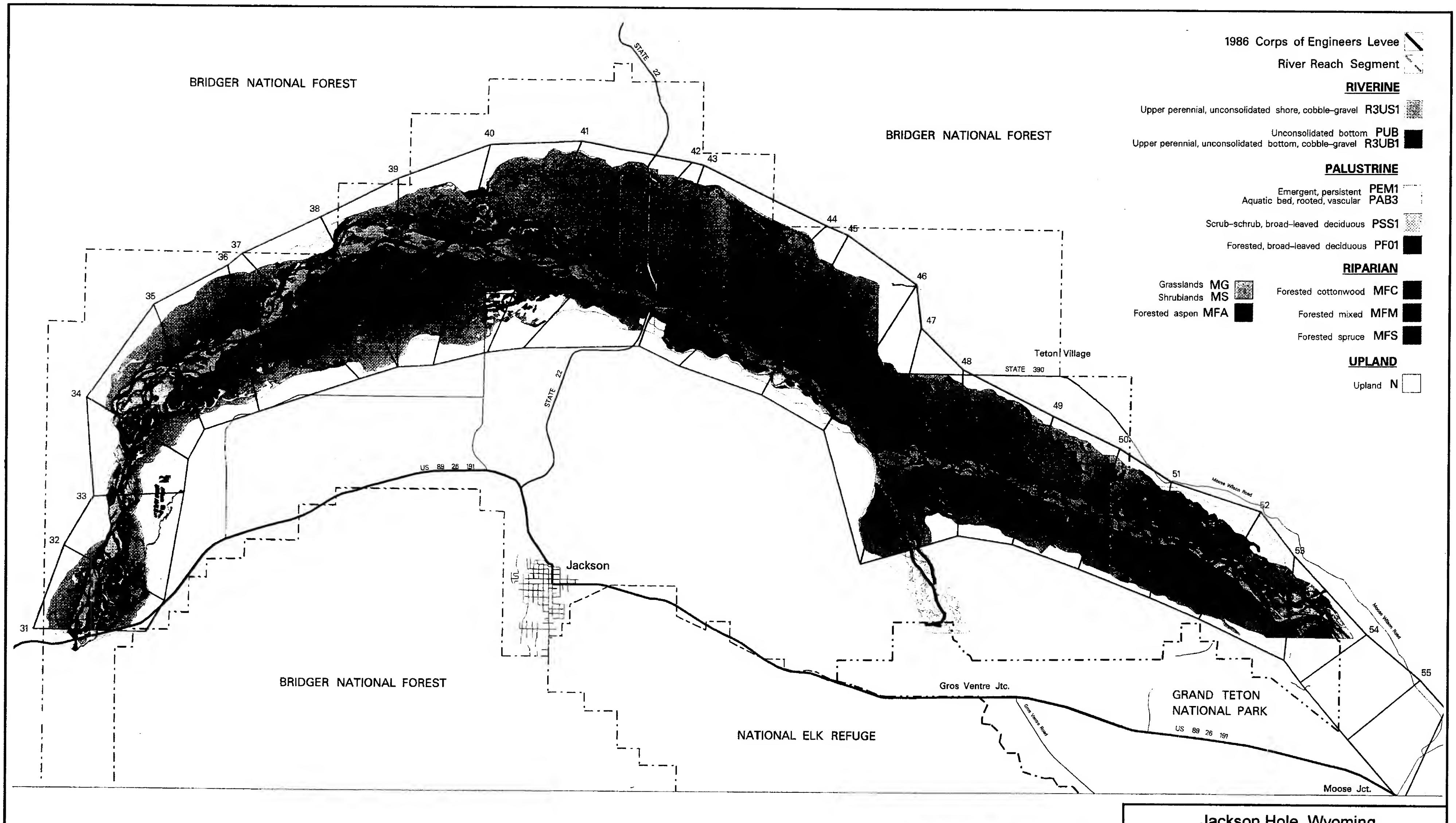


U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study

December 1999

Plate 14:
Vegetation Cover Types, 1956



U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study

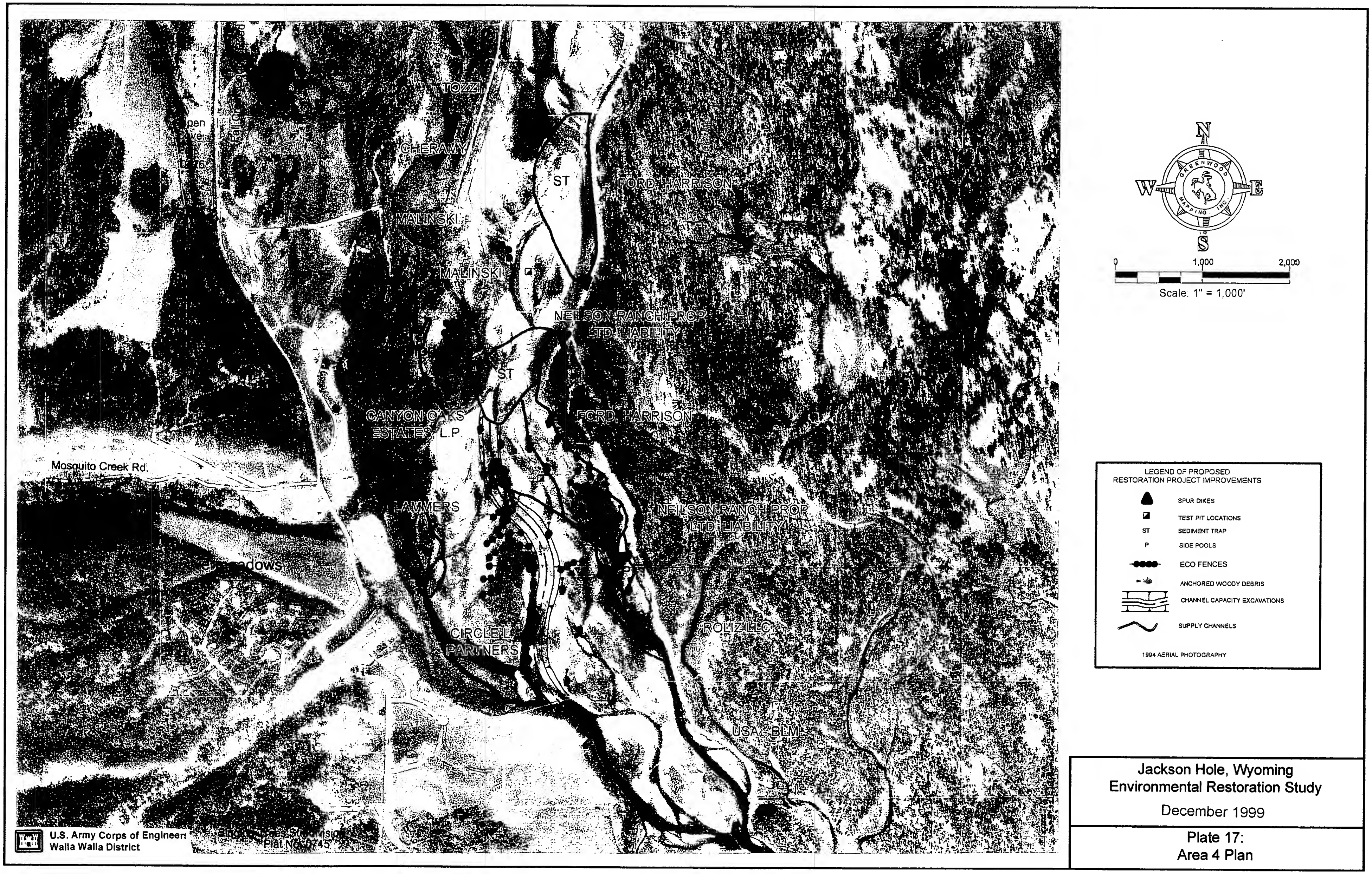
December 1999

Plate 15:
Vegetation Cover Types, 1986

Jackson Hole, Wyoming
Environmental Restoration Study

December 1999

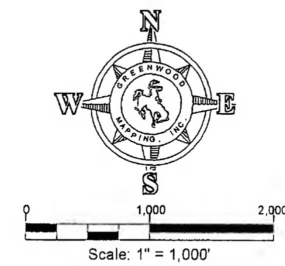
Plate 16:
Area 1 Plan



Jackson Hole, Wyoming
Environmental Restoration Study

December 1999

Plate 17:
Area 4 Plan



LEGEND OF PROPOSED RESTORATION PROJECT IMPROVEMENTS

- SPUR DIKES (REPRESENTS 5 SPUR DIKES)
- TEST PIT LOCATION
- P — SIDE POOLS
- LOG PLACEMENT
- ECO FENCES
- ANCHORED WOODY DEBRIS
- ROCK GRADE CONTROL
- CHANNEL CAPACITY EXCAVATIONS
- SUPPLY CHANNELS

1994 AERIAL PHOTOGRAPHY

U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study

December 1999

Plate 18:
Area 9 Plan

U.S. Army Corps of Engineers
Walla Walla District

Jackson Hole, Wyoming
Environmental Restoration Study

December 1999

Plate 19:
Area 10 Plan

APPENDIX A

FEASIBILITY STUDY COST SHARING AGREEMENT AND PROJECT STUDY PLAN

OF THE

JACKSON HOLE, WYOMING, ENVIRONMENTAL RESTORATION FEASIBILITY STUDY

JACKSON HOLE, WYOMING
ENVIRONMENTAL RESTORATION

The Jackson Hole, Wyoming, Environmental Restoration Project Study Plan, dated April 1996, is provided for your concurrence. This will be a "living" management system that will be updated as needed through the process defined within the document.

Bill MacDonald	CENPW-PL-PF	Study Manager	
Debbie Willis	CENPW-PM-PJ	Project Manager	

SPONSOR

Mike Gierau	Teton County Commissioner Chairperson	
Don Barney	Teton County, Project Manager	
Bill Glen	Teton County Natural Resource District, Board of Supervisors	
Rik Gay	Teton County Natural Resource District, Study Manager	

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT

LTC James S. Weller	CENPW-DE	District Engineer	
Mark Charlton	CENPW-DE (PM)	Programs and Project Management Division	
Clifford Fitzsimmons	CENPW-PL	Acting Chief, Planning Division	
Wayne John	CENPW-OP	Chief, Operations Division	
Richard Carlton	CENPW-RE	Chief, Real Estate Division	
Doug Frei	CENPW-EN	Acting Chief, Engineering Division	

AGREEMENT
BETWEEN THE UNITED STATES DEPARTMENT OF THE ARMY
AND
TETON COUNTY
FOR THE JACKSON HOLE, WYOMING, FEASIBILITY STUDY COST SHARING AGREEMENT AND PROJECT STUDY PLAN

THIS AGREEMENT is entered into this 23 **day of July, 1996**, by and between the United States Department of the Army (hereinafter the "Government"), represented by the District Engineer executing this Agreement, and the Teton County (hereinafter the "Sponsor").

WITNESSETH, that

WHEREAS, the Jackson Hole River and Wetland Restoration Study, Wyoming, was authorized by the U.S. Senate Committee on Environment and public Works in a Study Resolution of June 12, 1990, which stated:

> "The Secretary of the Army is hereby requested to review the report of the Chief of Engineers dated 28 June 1949, printed as House Document Numbered 531, Eighty-First Congress, Second Session, and other pertinent reports, with a view of determining the advisability of mitigating for fish and wildlife impacts resulting from construction, operations and maintenance of the Jackson Hole, Snake River, Wyoming project authorized by Public Law 516, Flood Control Act of 1950 and modified by Section 840 of Public Law 99-662, the Water Resources Development Act of 1986, including levees constructed by non-Federal interests."

The *Snake River in Wyoming Interim, Upper Snake River and Tributaries Study* was authorized by a March 1954 resolution of the U.S. Senate Committee on Public Works. It stated:

> "Resolved by the committee on Public Works of the United States Senate, that the Board of Engineers for Rivers and Harbors, created under Section 3 of the Rivers and Harbors Act, approved June 13, 1902, be, and is hereby, requested to review the report of the Chief of Engineers on the Columbia River and Tributaries, Northwestern United States, submitted in House Document Numbered 531, Eighty-First Congress, Second Session, with a view to determine whether any modification of the recommendations contained therein is advisable at this time, with particular reference to the Upper Snake River Basin above Weiser, Idaho."

WHEREAS, the U.S. Army Corps of Engineers has conducted a Reconnaissance Study to determine if there is Federal interest in: 1) extending or improving the current flood protection system; and 2) "...determining the advisability of mitigating for fish and wildlife impacts resulting from construction, operation, and maintenance of the existing project," pursuant to this authority, and has determined that further study in the nature of a "Feasibility Phase Study" (hereinafter the

"Study") is required to fulfill the intent of the Study authority and to assess the extent of the Federal interest in participating in a solution to the identified problem; and

WHEREAS, Section 105 of the Water Resources Development Act of 1986 (Public Law 99-662, as amended) specifies the cost sharing requirements applicable to the Study;

WHEREAS, the Sponsor has the authority and capability to furnish the cooperation hereinafter set forth and is willing to participate in Study cost sharing and financing in accordance with the terms of this Agreement; and

WHEREAS, the Sponsor and the Government understand that entering into this Agreement in no way obligates either party to implement a project and that whether the Government supports a project authorization and budgets it for implementation depends upon, among other things, the outcome of the Study and whether the proposed solution is consistent with the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* and with the budget priorities of the Administration;

NOW THEREFORE, the parties agree as follows:

ARTICLE I - DEFINITIONS

For the purposes of this Agreement:

A. The term "Study costs" shall mean all disbursements by the Government pursuant to this Agreement, from Federal appropriations or from funds made available to the Government by the Sponsor, and all negotiated costs of work performed by the Sponsor pursuant to this Agreement. Study costs shall include, but not be limited to: labor charges; direct costs; overhead expenses; supervision and administration costs; the costs of contracts with third parties, including termination or suspension charges; and any termination or suspension costs (ordinarily defined as those costs necessary to terminate ongoing contracts or obligations and to properly safeguard the work already accomplished) associated with this Agreement.

B. The term "Study period" shall mean the time period for conducting the Study, commencing with the release to the U.S. Army Corps of Engineers, Walla Walla District, of initial Federal feasibility funds following the execution of this Agreement and ending when the Assistant Secretary of the Army (Civil Works) submits the Feasibility Report to the Office of Management and Budget (OMB) for review for consistency with the policies and programs of the President.

C. The term "PSP" shall mean the Project Study Plan, which is attached to this Agreement and which shall not be considered binding on either party and is subject to change by the Government.

D. The term "negotiated costs" shall mean the costs of in-kind services to be provided by the Sponsor in accordance with the PSP.

E. The term "contracting officer" shall mean a representative of the Government with the authority to enter into, administer and/or terminate contracts and make related determinations and findings.

F. The term "fiscal year" shall mean one fiscal year of the Government. The Government fiscal year begins on October 1 and ends on September 30.

ARTICLE II - OBLIGATIONS OF PARTIES

A. The Government, using funds and in-kind services provided by the Sponsor and funds appropriated by the Congress of the United States, shall expeditiously prosecute and complete the Study, in accordance with the provisions of this Agreement and Federal laws, regulations, and policies.

B. In accordance with this Article and Article III of this Agreement, the Sponsor shall contribute cash and in-kind services equal to fifty (50) percent of total. The Sponsor may, consistent with applicable law and regulations, contribute up to twenty-five (25) percent of total Study costs through the provision of in-kind services. The in-kind services to be provided by the Sponsor, the estimated negotiated costs for those services, and the estimated schedule under which those services are to be provided are specified in the PSP. Negotiated costs shall be subject to an audit by the Government to determine reasonableness, allocability, and allowability.

C. The Sponsor understands that the schedule of work may require the Sponsor to provide cash or in-kind services at a rate that may result in the Sponsor temporarily diverging from the obligations concerning cash and in-kind services specified in paragraph B of this Article. Such temporary divergences shall be identified in the quarterly reports provided for in Article III.A. of this Agreement and shall not alter the obligations concerning costs and services specified in paragraph B of this Article or the obligations concerning payment specified in Article III of this Agreement.

D. If, upon the award of any contract or the performance of any in-house work for the Study by the Government or the Sponsor, cumulative financial obligations of the Government and the Sponsor would exceed **$350,000 annually ($175,000 Corps, $175,000 Sponsor combination of cash and in kind)**, the Government and the Sponsor agree to defer award of that and all subsequent contracts, and performance of that and all subsequent in-house work, for the Study until the Government and the Sponsor agree to proceed, but in no event shall such a deferral exceed two (2) years.

E. No Federal funds may be used to meet the Sponsor's share of Study costs unless the Federal granting agency verifies in writing that the expenditure of such funds is expressly authorized by statute.

F. The award and management of any contract with a third party in furtherance of this Agreement which obligates Federal appropriations shall be exclusively within the control of the Government. The award and management of any contract by the Sponsor with a third party in furtherance of

this Agreement which obligates funds of the Sponsor and does not obligate Federal appropriations shall be exclusively within the control of the Sponsor but shall be subject to applicable Federal laws and regulations.

ARTICLE III - METHOD OF PAYMENT

A. The Government shall maintain current records of contributions provided by the parties, current projections of total Study costs, and current projections of each party's share of total Study costs. At least quarterly, the Government shall provide the Sponsor a report setting forth this information. Total Study costs are currently estimated to be **$1,399,198 ($1,400,000)**, and the Sponsor's share of total Study costs is currently estimated to be **$700,000**. In order to meet the Sponsor's cash payment requirements, the Sponsor must provide a cash contribution estimated to be **$350,000**. The dollar amounts set forth in this Article are based upon the Government's best estimates, which reflect projected costs, price-level changes, and anticipated inflation. Such cost estimates are subject to adjustment by the Government and are not to be construed as the total financial responsibilities of the Government and the Sponsor.

B. The Sponsor shall provide its cash contribution required under Article II. B. of this Agreement in accordance with the following provisions:

1. For purposes of budget planning, the Government shall notify the Sponsor by March 15 of each year of the estimated funds that will be required from the Sponsor to meet the Sponsor's share of total Study costs for the upcoming fiscal year.

2. No later than **sixty (60) calendar days** prior to the scheduled date for the Government's issuance of the solicitation for the first contract for the Study or for the Government's anticipated first significant in-house expenditure for the Study, the Government shall notify the Sponsor in writing of the funds the Government determines to be required from the Sponsor to meet its required share of total Study costs for the first fiscal year of the Study. No later than thirty (30) calendar days thereafter, the Sponsor shall **verify to the satisfaction of the Government that the Sponsor has deposited the required funds in an escrow or other account acceptable to the Government, with interest accruing to the Sponsor.**

3. For the second and subsequent fiscal years of the Study, the Government shall, no later than sixty (60) calendar days prior to the beginning of the fiscal year, notify the Sponsor in writing of the funds the Government determines to be required from the Sponsor to meet its required share of total Study costs for that fiscal year, taking into account any temporary divergences identified under Article II.C. of this Agreement. No later than thirty (30) calendar days prior to the beginning of the fiscal year, the Sponsor shall make the full amount of the required funds available to the Government through the funding mechanism specified in paragraph B.2. of this Article.

4. The Government shall draw from the **escrow account** provided by the Sponsor such sums as the Government deems necessary to cover the Sponsor's share of contractual and in-house fiscal obligations attributable to the Study as they are incurred.

5. In the event the Government determines that the Sponsor must provide additional funds to meet its share of Study costs, the Government shall so notify the Sponsor in writing. No later than **sixty (60) calendar days** after receipt of such notice, the Sponsor shall make the full amount of the additional required funds available through the funding mechanism specified in paragraph B.2. of this Article.

C. Within ninety (90) days after the conclusion of the Study Period or termination of this Agreement, the Government shall conduct a final accounting of Study costs, including disbursements by the Government of Federal funds, cash contributions by the Sponsor, and credits for the negotiated costs of the Sponsor, and shall furnish the Sponsor with the results of this accounting. Within thirty (30) days thereafter, the Government, subject to the availability of funds, shall reimburse the Sponsor for the excess, if any, of cash contributions and credits given over its required share of total Study costs, or the Sponsor shall provide the Government any cash contributions required for the Sponsor to meet its required share of total Study costs.

ARTICLE IV - STUDY MANAGEMENT AND COORDINATION

A. To provide for consistent and effective communication, the Sponsor and the Government shall appoint named senior representatives to an Executive Committee: **Deputy District Engineer Project Management, Chief of Planning, Chief of Operations, Teton County Commissioner, and Teton County Natural Resource District Board Member**. Thereafter, the Executive Committee shall meet regularly until the end of the Study period.

B. Until the end of the Study period, the Executive Committee shall generally oversee the Study consistently with the PSP.

C. The Executive Committee may make recommendations that it deems warranted to the Government on matters that it oversees, including suggestions to avoid potential sources of dispute. The Government in good faith shall consider such recommendations. The Government has the discretion to accept, reject, or modify the Executive Committee's recommendations.

D. The Executive Committee shall appoint representatives to serve on a Study Management Team. The Study Management Team shall keep the Executive Committee informed of the progress of the Study and of significant pending issues and actions and shall prepare periodic reports on the progress of all work items identified in the PSP.

ARTICLE V - DISPUTES

Before a party to this Agreement may bring suit in any court concerning an issue relating to this Agreement, the party must first seek in good faith to resolve the issue through negotiation or other forms of non-binding, alternative dispute resolution mutually acceptable to the parties.

ARTICLE VI - MAINTENANCE OF RECORDS

A. Within sixty (60) days of the effective date of this Agreement, the Government and the Sponsor shall develop procedures for keeping books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to this Agreement to the extent and in such detail as will properly reflect total Study costs. These procedures shall incorporate, and apply as appropriate, the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to state and local governments at 32 Code of Federal Regulations (C.F.R). Section 33.20. The Government and the Sponsor shall maintain such books, records, documents, and other evidence in accordance with these procedures for a minimum of three (3) years after completion of the Study and resolution of all relevant claims arising therefrom. To the extent permitted under applicable Federal laws and regulations, the Government and the Sponsor shall each allow the other to inspect such books, documents, records, and other evidence.

B. In accordance with 31 United States Code (U.S.C.) Section 7503, the Government may conduct audits in addition to any audit that the Sponsor is required to conduct under the Single Audit Act of 1984, 31 U.S.C. Sections 7501-7507. Any such Government audits shall be conducted in accordance with Government Auditing Standards and the cost principles in Office of Management and Budget (OMB) Circular No. A-87 and other applicable cost principles and regulations. The costs of Government audits shall be included in total Study costs and shared in accordance with the provisions of this Agreement.

ARTICLE VII - RELATIONSHIP OF PARTIES

The Government and the Sponsor act in independent capacities in the performance of their respective rights and obligations under this Agreement, and neither is to be considered the officer, agent, or employee of the other. The Sponsor shall hold and save the Government free from all damages arising from performance of the Study as described in the Jackson Hole Wyoming Environmental Restoration Feasibility Phase Project Study Plan and appendix A thereto, attached hereto and incorporated by reference herein, except for damages due to the fault or negligence of the Government or its contractors.

ARTICLE VIII - OFFICIALS NOT TO BENEFIT

No member of or delegate to the Congress, nor any resident commissioner, shall be admitted to any share or part of this Agreement or to any benefit that may arise therefrom.

ARTICLE IX - FEDERAL AND STATE LAWS

In the exercise of the Sponsor's rights and obligations under this Agreement, the Sponsor agrees to comply with all applicable Federal and State laws and regulations, including Section 601 of Title VI of the Civil Rights Act of 1964 (Public Law 88-352) and Department of Defense Directive 5500.1 issued pursuant thereto and published in 32 C.F.R. Part 300~ as well as Army

Regulations 600-7, entitled *Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army*.

ARTICLE X - TERMINATION OR SUSPENSION

A. This Agreement shall terminate at the end of the Study Period; provided, that prior to such time and upon thirty (30) days written notice, either party may terminate or suspend this Agreement. In addition, the Government shall terminate this Agreement immediately upon any failure of the Sponsor to fulfill its obligations under Article III of this Agreement. In the event that either party elects to terminate this Agreement, both parties shall conclude their activities relating to the Study and proceed to a final accounting in accordance with Article III.C. of this Agreement. Upon termination of this Agreement, all data and information generated as part of the Study shall be made available to both parties.

B. Any termination of this Agreement shall not relieve the parties of liability for any obligations previously incurred, including the costs of closing out or transferring any existing contracts.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement, which shall become effective upon the date it is signed by the District Engineer for the U.S. Army Corps of Engineers, Walla Walla District.

DEPARTMENT OF THE ARMY

By Donald R. Curtis, Jr.
Lieutenant Colonel
Corps of Engineers
District Engineer
Walla Walla District
201 North Third Avenue
Walla Walla, WA 99362-1876

TETON COUNTY, WYOMING

Mike Gierau
Chairperson
Teton County Commission
Teton County, Wyoming

Attachment - Project Study Plan

CERTIFICATION REGARDING LOBBYING

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit standard Form-LLL, "Disclosure Form To Report Lobbying," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by Section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Mike Gierau, Chairperson
Teton County Commission
Teton County, Wyoming

FEASIBILITY PHASE
PROJECT STUDY PLAN

JACKSON HOLE, WYOMING
ENVIRONMENTAL RESTORATION

JACKSON HOLE, WYOMING
ENVIRONMENTAL RESTORATION
FEASIBILITY PHASE
PROJECT STUDY PLAN

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APPENDIX A
DETAILED COST ANALYSES

JACKSON HOLE, WYOMING
ENVIRONMENTAL RESTORATION
FEASIBILITY PHASE
PROJECT STUDY PLAN

1. PURPOSE.

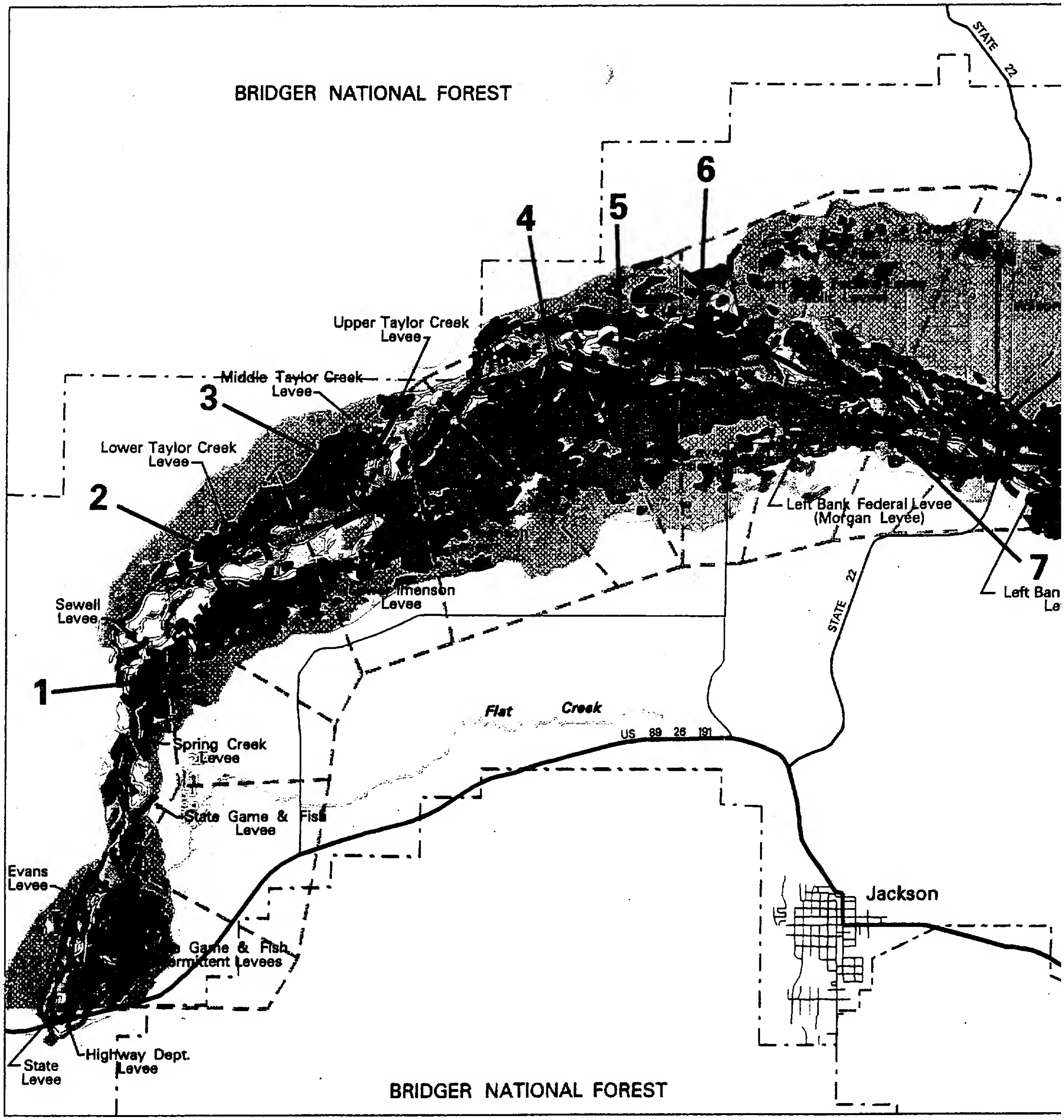
This Project Study Plan (PSP) is a plan of study that is used to define and manage development and performance of the Jackson Hole, Wyoming, Environmental Restoration (JHER) Feasibility Study. This PSP documents the assumptions, work tasks, products, and the level of detail that will be necessary during the Feasibility Study to determine the existing and the future without project conditions; formulate a range of alternatives; assess their effects; and present a clear rationale for the selection of water resource development and environmental restoration plan(s). This PSP includes the Baseline Feasibility Cost Estimate, Schedule, and the assignment of responsibilities. This PSP clearly defines work tasks and products, provides the U.S. Army Corps of Engineers, Walla Walla District (CENPW) management with a means for cost and schedule control, establishes the basis for changes, promotes both internal and external communications, and precludes review problems for the Feasibility Study. The intent of this JHER PSP is to add value to the Feasibility Study phase. In order to clarify cost-sharing responsibilities, the study obligations of the U.S. Army Corps of Engineers (Corps) and Teton County (referred to as the Sponsor throughout the remainder of this PSP) will be identified in accordance with the Water Resources Development Act of 1986 (WRDA, 1986).

2. SCOPE OF WORK.

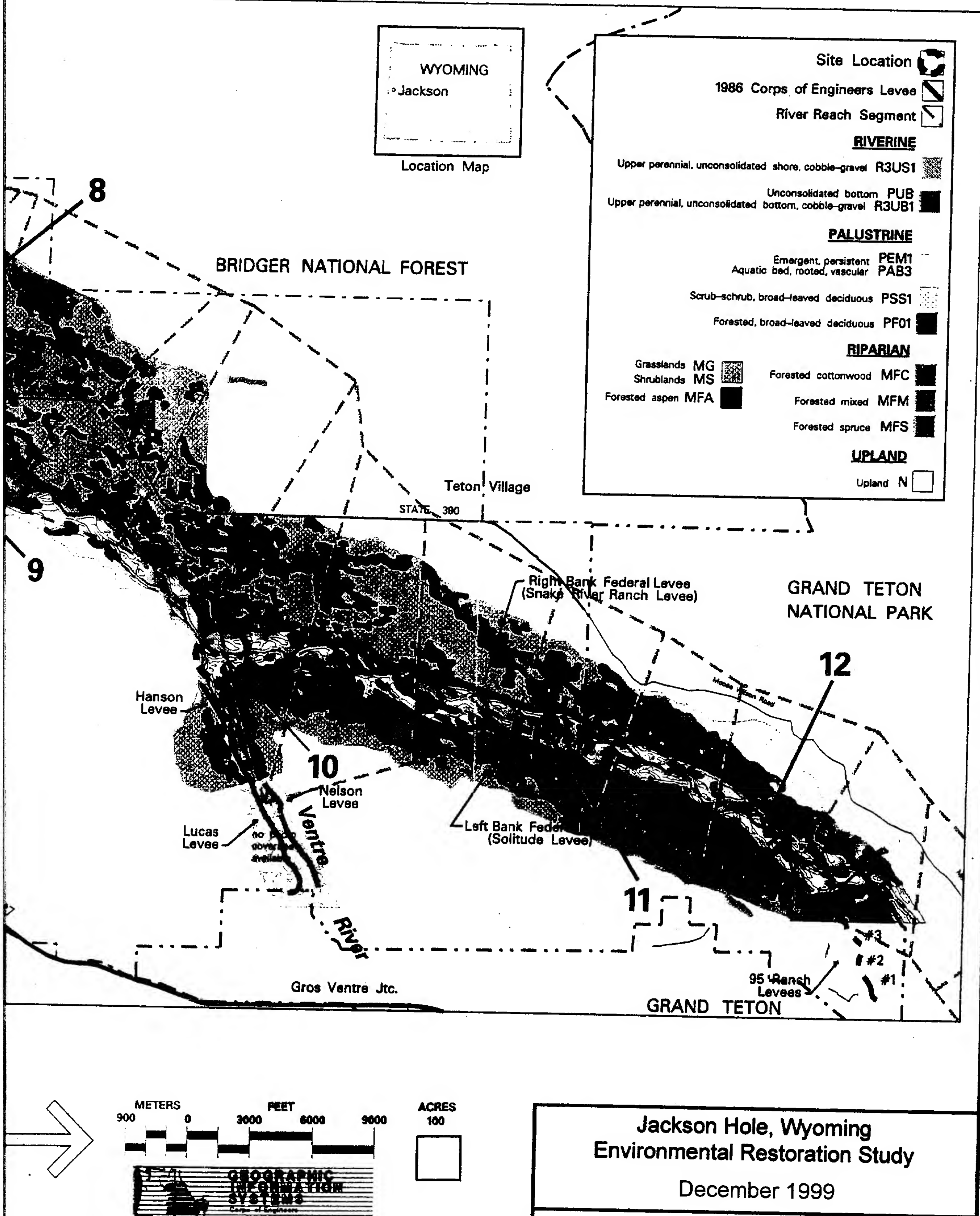
The intent of this PSP is to determine the feasibility of providing environmental restoration to riverine, wetland, and riparian habitats for four sites within the "active" river channel (or between flood control levees). This stretch lies between Grand Teton National Park and South Park Elk Feed Grounds in Jackson Hole, Wyoming (see plate 1 and 1-1 through 1-12).

The original study proposed in the January 1995 PSP cost in excess of $3 million and involved the entire 500-year floodplain from Moose to South Park Feed Ground. Although this was an admirable approach to ecosystem restoration, it was far to costly for the Sponsor. To reduce the cost of the study, CENPW had to formulate an analysis to reduce the overall scope of the study.

A senior hydrologist and respected wildlife biologist reviewed aerial photography and data generated during the reconnaissance study to select 12 sites that provide the best opportunity for restoration from a fluvial geomorphology and wildlife habitat standpoint (plates 1-1 through 1-12). A PSP was then developed for the 12 specific sites. The cost of the study was reduced from over $3 million to just under $2 million, a significant reduction but still out of the range of the Sponsor's fiscal ability. It became apparent that further efforts to reduce cost could not be effective without further reductions in the overall scope of the study.



U.S. Army Corps of Engineers
Walla Walla District



Jackson Hole, Wyoming
Environmental Restoration Study

December 1999

Plate 2
12 Reconnaissance Sites

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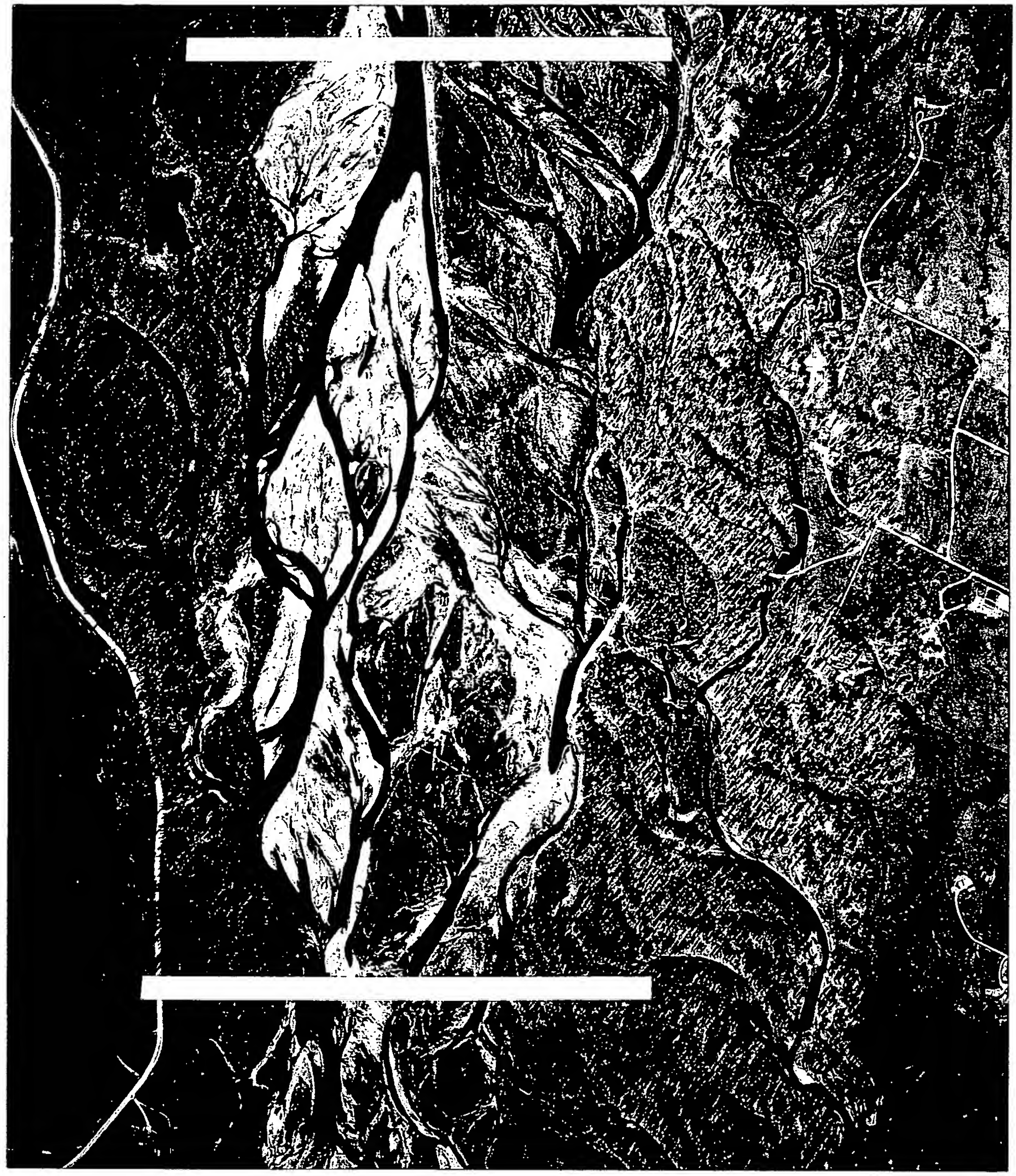
Scale: 1:12,000

Jackson Hole, Wyoming
Environmental Restoration Project
Plate 1 – 1



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Jackson Hole, Wyoming
Environmental Restoration Project
Plate 1 – 2

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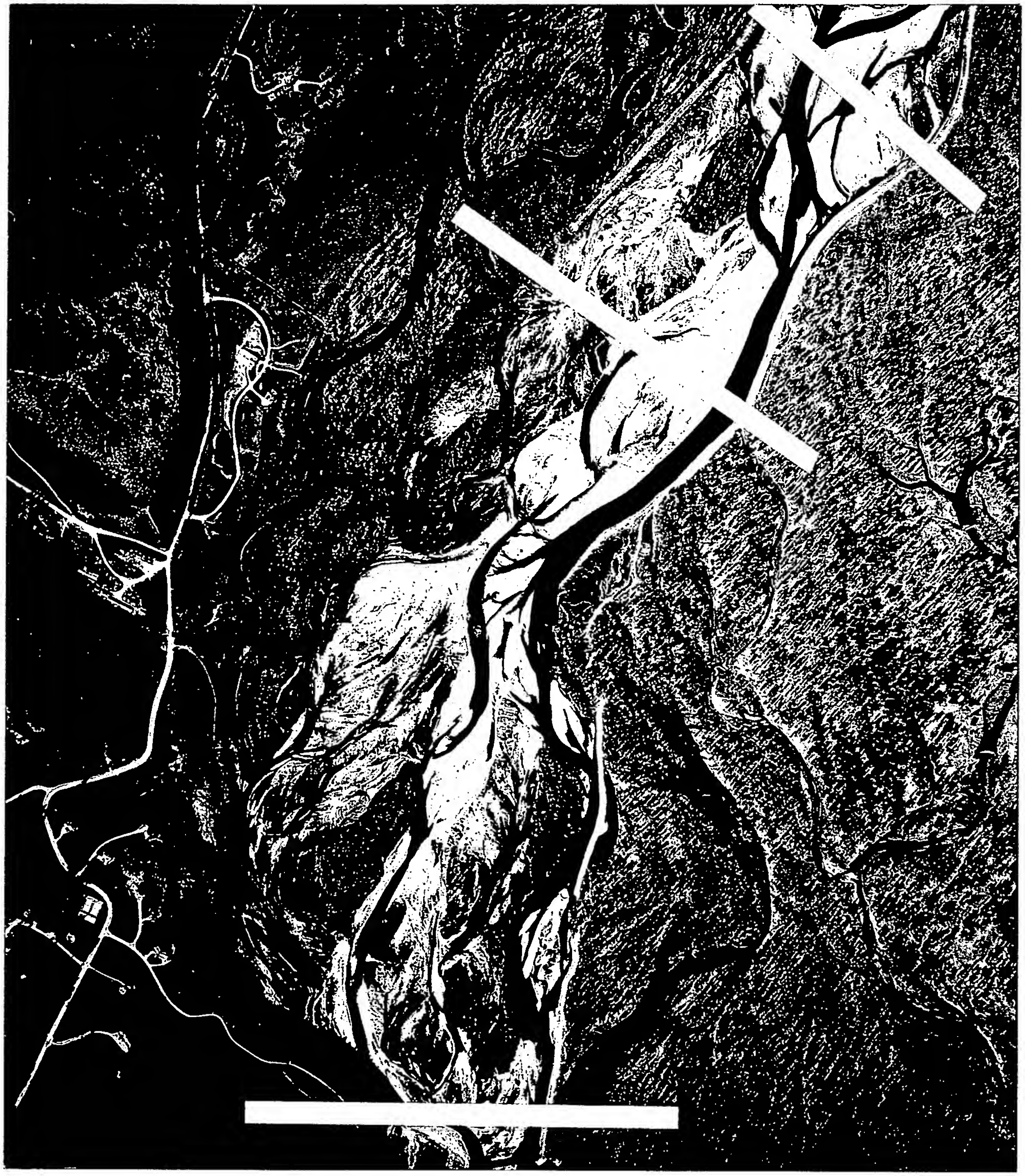
Jackson Hole, Wyoming
Environmental Restoration Project
Plate 1 – 3



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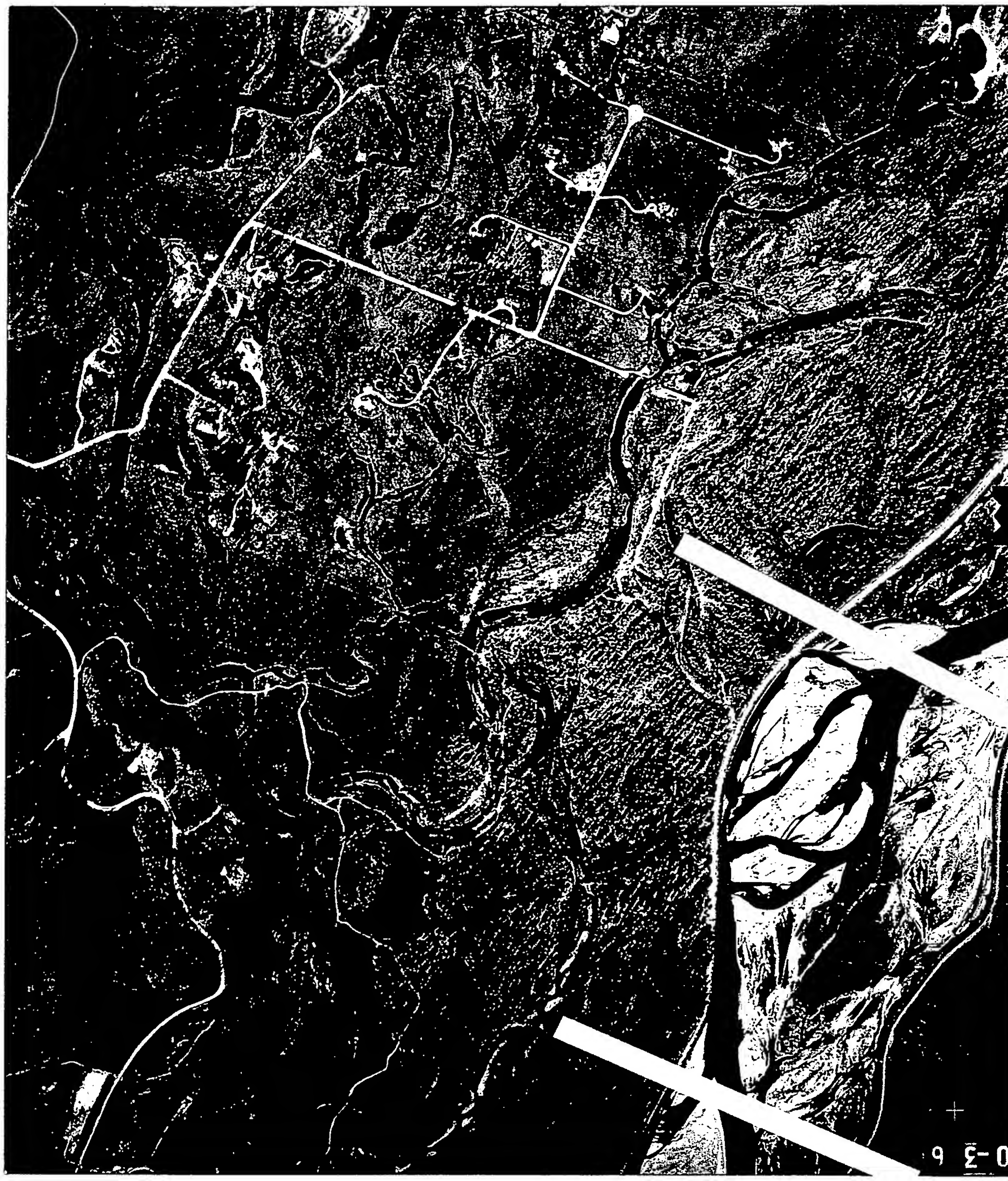
Jackson Hole, Wyoming
Environmental Restoration Project
Plate 1 - 4, 5



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Jackson Hole, Wyoming
Environmental Restoration Project
Plate 1 – 6

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Jackson Hole, Wyoming
Environmental Restoration Project
Plate 1 – 7

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Jackson Hole, Wyoming
Environmental Restoration Project
Plate 1 – 8, 9

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Jackson Hole, Wyoming
Environmental Restoration Project
Plate 1 - 10

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Jackson Hole, Wyoming
Environmental Restoration Project
Plate 1 – 11

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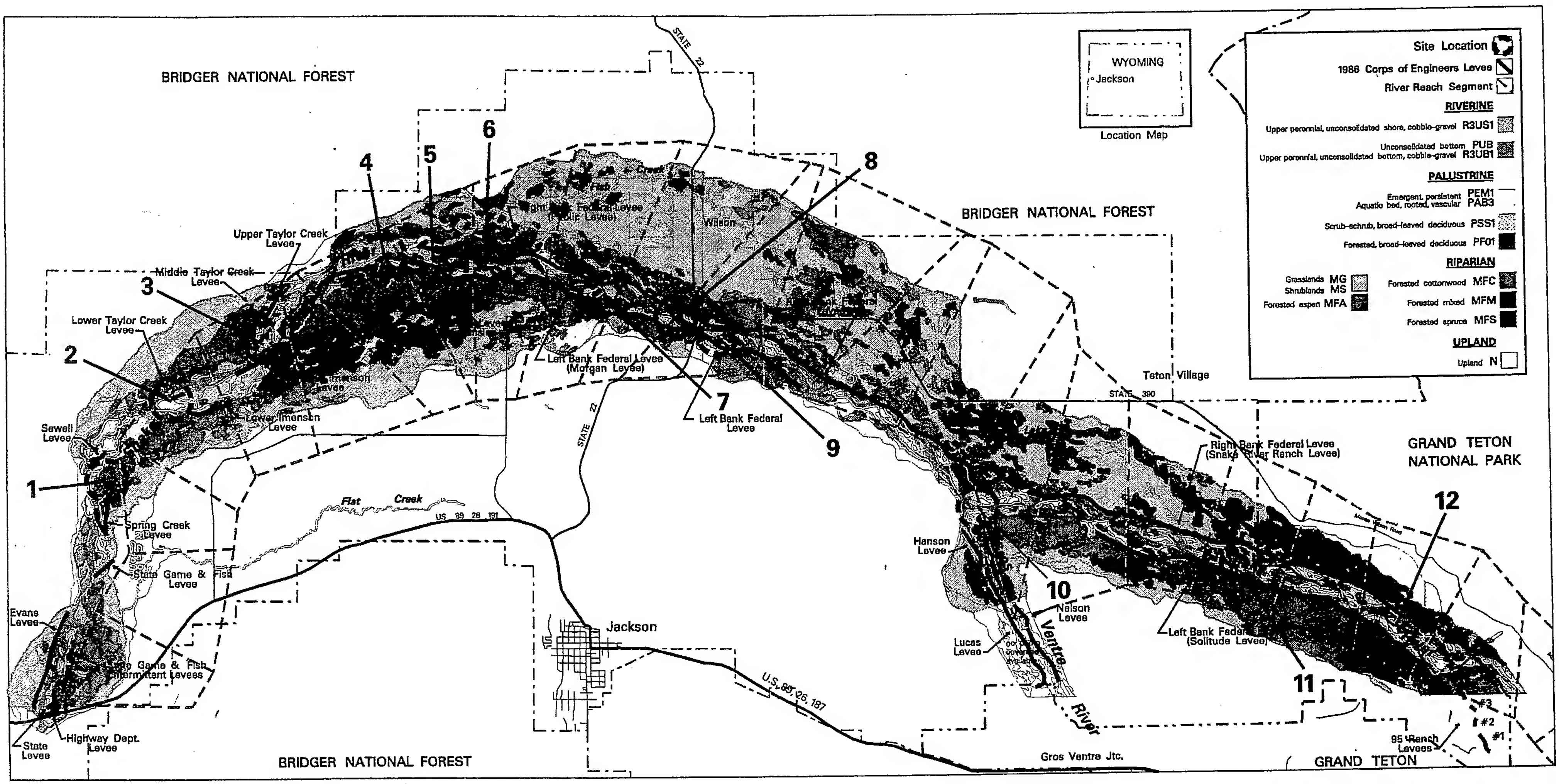
Jackson Hole, Wyoming
Environmental Restoration Project
Plate 1 – 12



Jackson Hole, Wyoming
Environmental Restoration Project Map
Site Locations 1 – 12

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PLATE 1

In an effort to reduce the scope, it was decided to determine and describe the overall environmental significance of each site. The overall study area has high national environmental significance as described in the Jackson Hole, Wyoming, Flood Damage Reduction, Fish and Wildlife Habitat Restoration, Reconnaissance Report (June 1993). To formulate a reduced scope, each of the 12 sites was evaluated in regard to its individual significance.

The Concept of Significance.

In 1983, the U.S. Water Resources Council published the *Economic and Environmental Principals and Guidelines for Water and Related Land Resources Implementation Studies* (P&G). The methodology in P&G is the analytical procedure currently used by the Corps in evaluating alternative water resources projects. To be considered in plan formulation and evaluation, P&G requires that environmental resources be "significant." Significant environmental resources are defined as those that are institutionally, publicly, or technically recognized as important. As defined in P&G, the term of "significant" means "likely to have a material bearing on the decision making process." In terms of environmental plan formulation and evaluation, the significance of environmental resources based on their non-monetary values may be established by institutional, public, or technical recognition of the importance of the environmental resources or attributes in the study area.

<u>Institutional Recognition</u> - The study areas are institutionally recognized by several national laws and regulations. Part of the proposed study is in Grand Teton National Park with the remainder immediately downstream and adjacent. The southern most section of the study area is adjacent to South Park Elk Feed Ground (a state preserve for wintering elk). Within the project area are six bald eagle nesting territories and habitat for five other nationally recognized endangered species. Over 50 percent of the project is classified as wetlands, which are protected by the Clean Water Act. The scarcity of structural and biological resources which directly support institutional resources will be addressed in this study.

<u>Public Recognition</u> - As indicated in the project support section of this document, the study area receives significant interest from local and regional environmental groups. The study area is also used by sportsman and recreationists from across the United States. The area, located between a national park and national forest, has considerable recreational value. The fine spotted cutthroat trout is an endemic wild fishery that provides an $11 million fishery to the county. The study has the potential to improve its value .

<u>Technical Recognition</u> - Spring creeks are relatively small streams fed by groundwater discharges of clean, clear water of relatively uniform annual temperature. They provide the critical spawning habitat for fine spotted cutthroat trout, which in turn provide a forage base for bald eagles. All eagle nesting habitats in the project area are associated with spring creeks.

All 12 sites were ranked individually based on their institutional, public, and technical recognition.

JACKSON HOLE RESTORATION FEASIBILITY STUDY (SITE RESTORATION - COMPARING 12 ALTERNATIVE SITE LOCATIONS)				
CRITERIA RATING INDICES: BEST 1; AVERAGE 2; WORST 3				
RAW SCORES:	NATIONAL SIGNIFICANCE CRITERIA			
	Institutional Recognition	Public Recognition	Technical Recognition	Totals
	(1)	(2)	(3)	
MEASURE:				
ALTERNATIVE 1	1	1	1	3
ALTERNATIVE 2	1	1	1	3
ALTERNATIVE 3	1	1	1	3
ALTERNATIVE 4	1	1	2	4
ALTERNATIVE 5	2	2	3	7
ALTERNATIVE 6	2	2	3	7
ALTERNATIVE 7	2	2	2	6
ALTERNATIVE 8	3	3	3	9
ALTERNATIVE 9	1	1	3	5
ALTERNATIVE 10	1	1	1	3
ALTERNATIVE 11	1	2	2	5
ALTERNATIVE 12	1	2	2	5

Multiobjective Analysis.

To further refine the scoping effort, a multiobjective approach was developed. Objectives developed with public input during the reconnaissance phase and refined at the Reconnaissance Review Conference were used in a matrix analysis. The study objectives were defined as: wetland restoration - riverine and palustrine; riparian restoration - island protection and restoration; and endangered species habitat protection and creation.

A multiobjective analysis was conducted using the following objectives:

a. Channel Creation. Channel creation to restore fisheries - wetland values dependent on surplus gravel and disposal options (*i.e.*, users of gravel).

b. Island Protection. Island protection measures to preserve riparian island values.

c. Island Restoration. Island restoration measures to restore lost riparian values.

d. <u>Fish Habitat Creation</u>. Fish habitat creation (low energy areas in high energy environments) through stream structure alteration (*i.e.*, spur dikes).

e. <u>Headgate Opportunities</u>. Headgate opportunities to provide for future water diversions to restore spring creeks - wetland-riparian habitats.

JACKSON HOLE RESTORATION FEASIBILITY STUDY (SITE RESTORATION - COMPARING 12 ALTERNATIVE SITE LOCATIONS)						
CRITERIA RATING INDICES: BEST 1, AVERAGE 2, WORST 3						
RAW SCORES:	MULTIOBJECTIVE ENVIRONMENTAL CRITERIA					
	Channel Creation	Island Protection	Island Restoration	Fish Habitat Creation	Headgate Opportunities	Totals
	(1)	(2)	(3)	(4)	(5)	
MEASURE:						
ALTERNATIVE 1	1	1	1	1	3	7
ALTERNATIVE 2	1	1	1	1	2	6
ALTERNATIVE 3	1	1	1	1	1	5
ALTERNATIVE 4	1	1	1	1	3	7
ALTERNATIVE 5	2	2	2	2	1	9
ALTERNATIVE 6	3	2	2	2	3	12
ALTERNATIVE 7	3	1	1	1	2	8
ALTERNATIVE 8	3	3	3	3	3	15
ALTERNATIVE 9	1	2	2	2	1	8
ALTERNATIVE 10	2	1	1	1	1	6
ALTERNATIVE 11	3	2	1	1	2	9
ALTERNATIVE 12	3	2	2	2	3	12

Integration of Multiobjective Analysis.

The values relating to overall national significance and environmental engineering feasibility were integrated and the multiobjective analysis was given a 1.5 weight to select the four sites that provide the best overall opportunity for success. The multiobjective approach was given additional "weight" because the sites providing the most opportunity provided a synergistic effect and the greatest overall opportunity. Six sites provided similar opportunity. Three sites on the downstream reach had very similar ratings and opportunities for restoration. The study team decided to allow the scoping process with local input and specific knowledge of property ownership and cultural concerns to select the best site of the three downstream sites of equal value. The four sites selected are one of either site 1, 2, or 3 and sites 4, 9, and 10.

JACKSON HOLE RESTORATION FEASIBILITY STUDY
(SITE RESTORATION - COMPARING 12 ALTERNATIVE SITE LOCATIONS)

CRITERIA RATING INDICES:

BEST	1
AVERAGE	2
WORST	3

RANKED INDEXED SCORES:

		APPLY 28.5% IMPORTANCE FACTOR TO 3 PUBLIC AWARENESS CRITERIA			APPLY 71.5% IMPORTANCE FACTOR TO 5 MULTIOBJECTIVE ENVIRONMENTAL CRITERIA			
		Index Application Rate Per Criteria	Number of Criteria	Total Index Points	Index Application Rate per Criteria	Number of Criteria	Total Index Points	Grand Total Index Points
RATING:								
BEST	1	0.095	3	0.285	0.143	5	0.715	1
AVERAGE	2	0.19	3	0.57	0.286	5	1.43	2
WORST	3	0.285	3	0.855	0.429	5	2.145	3

	NATIONAL SIGNIFICANCE CRITERIA			MULTIOBJECTIVE ENVIRONMENTAL CRITERIA					
	Institutional Recognition	Public Recognition	Technical Recognition	Channel Creation	Island Protection	Island Restoration	Fish Habitat Creation	Headgate Opportunities	Total
MEASURE	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Alternative 3	0.095	0.095	0.095	0.143	0.143	0.143	0.143	0.143	1
Alternative 2	0.095	0.095	0.095	0.143	0.143	0.143	0.143	0.286	1.143
Alternative 10	0.095	0.095	0.095	0.286	0.143	0.143	0.143	0.143	1.143
Alternative 1	0.095	0.095	0.095	0.143	0.143	0.143	0.143	0.429	1.286
Alternative 4	0.095	0.095	0.19	0.143	0.143	0.143	0.143	0.429	1.381
Alternative 9	0.095	0.095	0.285	0.143	0.286	0.286	0.286	0.143	1.619
Alternative 7	0.19	0.19	0.19	0.429	0.143	0.143	0.143	0.286	1.714
Alternative 11	0.095	0.19	0.19	0.429	0.286	0.143	0.143	0.286	1.762
Alternative 5	0.19	0.19	0.285	0.286	0.286	0.286	0.286	0.143	1.952
Alternative 12	0.095	0.19	0.19	0.429	0.286	0.286	0.286	0.429	2.191
Alternative 6	0.19	0.19	0.285	0.429	0.286	0.286	0.286	0.429	2.381
Alternative 8	0.285	0.285	0.285	0.429	0.429	0.429	0.429	0.429	3

The objective of this study is to provide site-specific restoration measures. The sites were selected based on a multiobjective analysis. Formulation of the restoration activities focus on examining the condition of the existing ecosystem and determining the feasibility of restoring degraded ecosystem structure, function, and dynamic processes to a less degraded and more natural condition. Ecosystem restoration provides a more comprehensive approach than focusing only on fish and wildlife habitat for addressing problems associated with disturbed and degraded ecological resources.

The primary components of an ecosystem are structure and functions. An ecosystem's structure is comprised of abiotic (non-living) elements (*i.e.*, air, water, soil, *etc.*), producers (*i.e.*, plants and animals), consumers, and decomposers. The principal functions of an ecosystem are the flow of energy and cycling of nutrients within the ecosystem. This study will investigate structural and functional degradation using historic and current data. Through the development

of new studies, the study will also determine pre-project conditions, existing conditions, and the future (both with and without project) conditions (see table 1 and plate 2).

Table 1. Historical and Future Timeline				
1850	1907	1956	2000	2050
Euro-American Contact	Construction of Jackson Lake Dam	Construction of Federal Levees	Project Life Begins	Project Evaluation Period Ends

The following steps are critical to the plan formulation study process:

a. Existing Conditions. A definition of existing conditions in the study area (defined as year 2000).

(1) A measurement of ecological resources through remote sensing, on the ground surveys, and community modeling of habitat.

(2) A determination of the influence of hydrology on surface and groundwater conditions in the study reach.

(3) A study of the geomorphology of the study reach, including outside influences that directly impact the study reach.

b. Future Conditions. An estimation of future conditions (year 2050) without restoration project improvements.

c. Restoration Measures. An identification and evaluation of the specific restoration measures included in the reconnaissance report approved at the Reconnaissance Review Conference on March 31, 1994. The study includes a detailed analysis of restoration measures at four specific sites. Each site was specifically formulated to provide the maximum environmental restoration opportunity.

(1) Channel stabilization to restore fisheries - wetland values dependent on surplus gravel and disposal options (*i.e.*, users of gravel).

(2) Island protection measures to preserve riparian island values.

(3) Island restoration measures to restore lost riparian values.

(4) Fish habitat creation (low energy areas in high energy environments) through stream structure alteration (*i.e.*, spur dikes).

(5) Headgate opportunities to provide for future water diversions to restore spring creeks, wetlands, and riparian habitats.

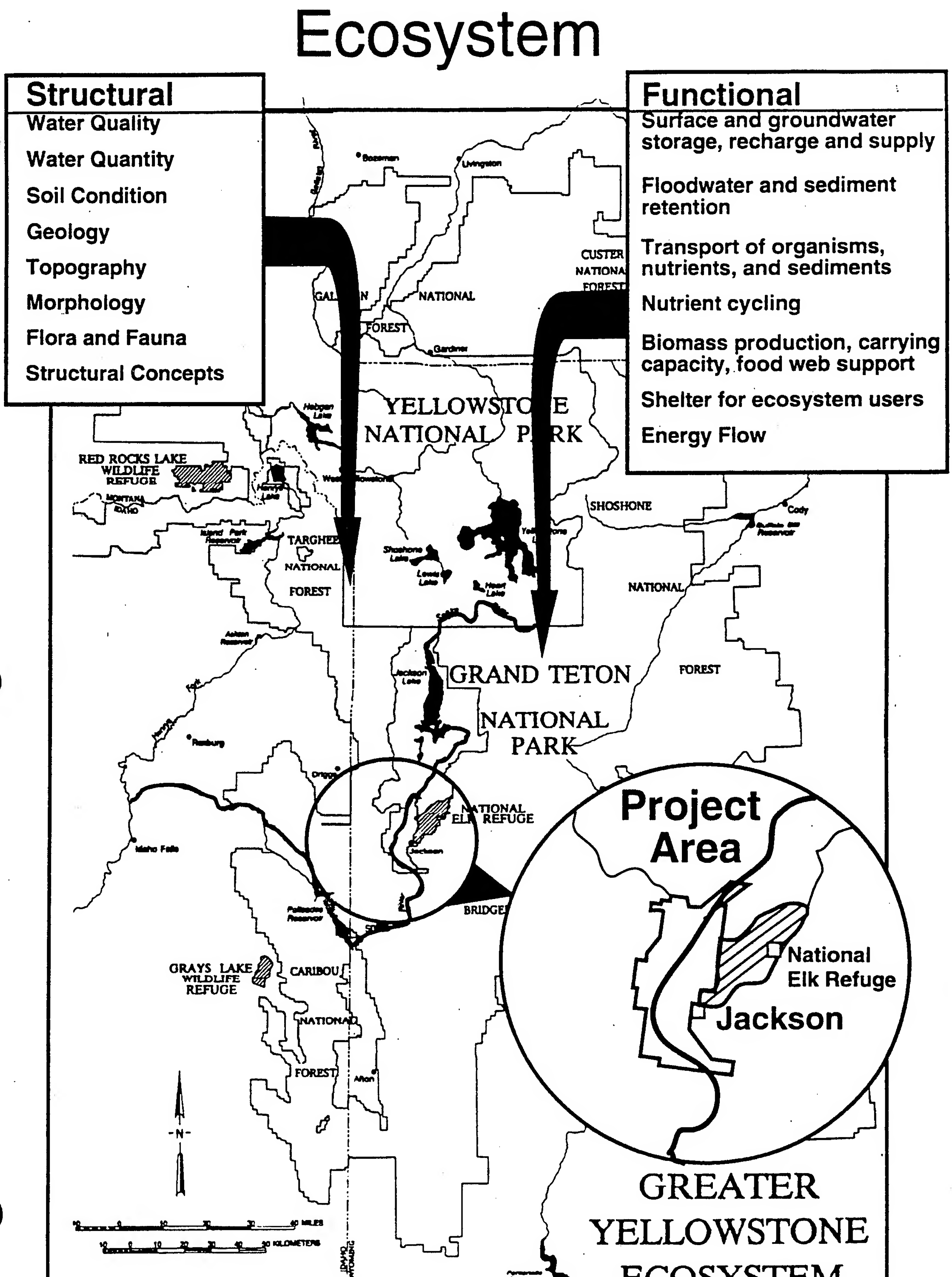
Ecosystem
Structural
Water Quality
Water Quantity
Soil Condition
Geology
Topography
Morphology
Flora and Fauna
Structural Concepts
Functional
Surface and groundwater storage, recharge and supply
Floodwater and sediment retention
Transport of organisms, nutrients, and sediments
Nutrient cycling
Biomass production, carrying capacity, food web support
Shelter for ecosystem users
Energy Flow
YELLOWSTONE NATIONAL PARK
GRAND TETON NATIONAL PARK
NATIONAL ELK REFUGE
RED ROCKS LAKE WILDLIFE REFUGE
GRAYS LAKE WILDLIFE REFUGE
TARGHEE NATIONAL FOREST
CARIBOU NATIONAL FOREST
SHOSHONE NATIONAL FOREST
CUSTER NATIONA
NATIONAL
FOREST
BRIDGE
Project Area
National Elk Refuge
Jackson
GREATER YELLOWSTONE ECOSYSTEM
N
MILES
KILOMETERS
IDAHO
WYOMING

Plate 2

Total restoration of the Jackson Hole study area is not the goal of this study. The goal of this study is to determine cost-efficient improvements that can be made at the four priority sites with a "responsible" (as defined by the public, their representatives, and the Corps) expenditure of capital funds. The study will be innovative and will strive towards identifying a broad range of alternative actions. The alternatives will range from the most basic concepts (those that can be undertaken with small expenditures and a high certainty of success) to more innovative, comprehensive, visions with higher cost and risk.

3. DESCRIPTION OF THE STUDY AREA.

The study area is limited to four specific sites within the "active" river of the Snake River in Jackson Hole, Wyoming, area. This area lies between Moose, Wyoming (near the southern boundary of Grand Teton National Park) and the U.S. Highway 26 Bridge over the Snake River (about 7 miles south of Jackson, Wyoming). Plate 1 contains a map of the study area.

The study area is part of the 18-million acre Greater Yellowstone Ecosystem that surrounds the world's first national park (see plate 2). The area, rich in unique plant and animal life, is one of the Nation's prized environmental resources. A recent decision to reintroduce the Northern Rocky Mountain Wolf to the area ensures that all animal species present when European man first set foot on this continent are once again present.

The Snake River bisects this region, providing the ecosystem with critical hydrologic processes. The river historically occupied a wide floodplain and was highly braided. This is nature's way of dissipating energy resulting from high water velocities associated with steep, titled, outwash, river plains.

Through time, regional hydrology changes have occurred. The Snake River has been confined and straightened by levees that modify river hydraulics and concentrate flows. Restriction of the braided-channel pattern has resulted in higher flow concentration and, possibly, higher velocities. The disruption of the random pattern of braided channels has resulted in more frequent attack on the islands remaining within the levee reach. Eroded materials are carried downstream as sediment and are deposited in a lower-velocity river reach. These ecosystem changes have caused the deterioration of critical habitat for endangered species and the slow, but steady, loss of a significant national resource.

4. SPONSOR SUPPORT.

A local Steering Committee coordinated the management of the reconnaissance-level study with various Federal, state and local agencies, and environmental groups. The Steering Committee was comprised of representatives of the public, Federal and State agencies, and special interest groups. The committee obtained public views and comments on proposals, plans of study, scoping, impacts of proposed alternatives, and draft documents. At regular meetings during the reconnaissance study, the Steering Committee informed interested parties of the project's progress to avoid misunderstandings. Local news reporters and Congressional staff attended meetings. The Steering Committee membership consisted of the following groups:

Teton County	Steve Thomas, Commissioner
	Grant Larson, Commissioner
	Sandy Shuptrine, Commissioner
	Dale Barbour, Commissioner
	Don Barney
Bureau of Land Management	David Harper
U.S. Fish and Wildlife Service (USFWS)	Chuck Davis
	Steve Lockman
	Art Anderson
U.S. Forest Service	Chuck Jones
	Rick Hudson
Soil Conservation Service	John Kremer
U.S. National Park Service	Marshall Gingery (Retired)
U.S. Bureau of Reclamation	Brian Pridgeon
U.S. Environmental Protection Agency	Vern Helbig
The Corps, Omaha District	Ed Gooley
Wyoming Game & Fish Department (Cheyenne)	Tom Collins
Wyoming Game & Fish Department (Fisheries)	Jon Erickson (Retired)
	John Kiefling
Wyoming Game & Fish Department (Wildlife)	Tom Toman
Greater Yellowstone Coalition	Michael Whitfield
Jackson Hole Alliance	Scott Garland
Trout Unlimited	Tom Campbell
	Ed Ingold (Retired)
	Bob Patrick
Wyoming Water Development Commission	Leslie Petersen
Teton County Conservation District	Rik Gay
	Kelly Lockhart

The Corps' restoration study has received broad public support and interest. In particular, there has been strong local participation in the restoration study since its conception during the National Environmental Protection Act (NEPA) review of the Corps' Operation and Maintenance (O&M) proposal in May 1990. The study was first identified in the Record of Decision (ROD) and later endorsed in a plan of study developed in May 1990. The Jackson Hole River and Wetland Restoration Study, Wyoming, was authorized by the U.S. Senate Committee on Environment and Public Works in a study resolution of June 12, 1990. The restoration study and the related Water Resource Development Act, Project Modifications for Improvement of Environment, Section 1135 study have received considerable local media coverage, which is a positive step in regard to the Corps' new environmental mandate. These actions generated the

first Western Wetlands Development and Restoration Workshop. The workshop was sponsored by the Corps and the U.S. Bureau of Reclamation and was held in Jackson, Wyoming, in June 1992.

At the Reconnaissance Review Conference held March 31, 1994, eight representatives from private industry, private property owners, environmental agencies and organizations, and Teton County traveled to Portland, Oregon, to express interest in the approval of a feasibility-level study.

The local representatives from Jackson Hole, Wyoming, stated clear support for proceeding with the Feasibility Phase. Two Teton County Commissioners, Steve Thomas and Grant Larson, stated that Teton County is interested in sponsoring the Feasibility Study.

Coordination has continued with the county in an effort to reduce the scope of the study to a cost affordable by the county. Don Barney, Teton County Road and Levee Supervisor, and Rik Gay, Teton County Conservation District, have provided guidance and leadership at the local level. Mrs. Sandy Shuptrine, Teton County Commissioner, has provide continuity from the previous (November 1994) commission to the present commissioners. The CENPW met with the Commissioners on August 14, 1995, to further define the county's concerns and financial ability. The PSP is based on the CENPW most recent coordination efforts and direction from the U.S. Army Corps of Engineers, North Pacific Division (CENPD).

5. <u>STUDY AUTHORIZATION</u>.

In 1964, a continuous system of Federal levees was completed along a 13-mile reach of the Snake River. These original levees were extended through various State and Federal authorities, as discussed subsequently in this report. The WRDA, 1986, turned the responsibility of maintaining these levees over to the Secretary of the Army. A Reconnaissance Report was prepared in response to two Congressional directives that provide authority to study the existing system to determine if there is Federal interest in: 1) extending or improving the current flood protection system; and 2) "...determining the advisability of mitigating for fish and wildlife impacts resulting from construction, operation, and maintenance of the existing project."

By responding to two separate authorities, this proposed Feasibility Study provides a comprehensive approach to better serve the public and improve overall management efficiency. This approach is in agreement with the CENPW, *Position Paper*, dated August 14, 1992, which was developed with CENPD and was approved on October 21, 1992, by the U.S. Army Corps of Engineers, Headquarters (HQUSACE). Addressing the two study authorities in a combined effort responds to the need for a common without-project condition scenario for the common study area. This proposal addresses primarily environmental restoration and not additional flood damage reduction. Neither the Sponsor nor the Corps intends to increase the flood damage reduction project area of protection. Rather, the intent is to provide environmental restoration in a manner which will cause reduced maintenance. An example would be to reduce impinging flows on existing levees.

The Jackson Hole River and Wetland Restoration Study, Wyoming, was authorized by the U.S. Senate Committee on Environment and Public Works in a Study Resolution of June 12, 1990. This Resolution stated:

> "The Secretary of the Army is hereby requested to review the report of the Chief of Engineers dated 28 June 1949, printed as House Document Numbered 531, Eighty-First Congress, Second Session, and other pertinent reports, with a view of determining the advisability of mitigating for fish and wildlife impacts resulting from construction, operations and maintenance of the Jackson Hole, Snake River, Wyoming project authorized by Public Law 516, Flood Control Act of 1950 and modified by Section 840 of Public Law 99-662, the Water Resources Development Act of 1986, including levees constructed by non-Federal interests."

The Snake River in Wyoming Interim, Upper Snake River and Tributaries Study was authorized by a March 1954 resolution of the U.S. Senate Committee on Public Works. It stated:

> "Resolved by the committee on Public Works of the United States Senate, that the Board of Engineers for Rivers and Harbors, created under Section 3 of the Rivers and Harbors Act, approved June 13, 1902, be, and is hereby, requested to review the report of the Chief of Engineers on the Columbia River and Tributaries, Northwestern United States, submitted in House Document Numbered 531, Eighty-First Congress, Second Session, with a view to determine whether any modification of the recommendations contained therein is advisable at this time, with particular reference to the Upper Snake River Basin above Weiser, Idaho."

Within the Corps' Civil Works program, priority will be given to projects for commercial navigation, flood damage reduction, <u>and restoration of degraded ecosystem functions and values, including its hydrology, plant and animal communities, and/or portions thereof, to a less degraded ecological condition</u> [Engineering Circular (EC) 11-2-166 *Annual Programs and Budget Requests for Civil Works Activities*). Within the ecosystem restoration category of studies, budgetary priority will be given to cases where Corps projects contributed to the degradation of the ecosystem and where modification of existing Corps projects is the most cost-effective means of restoring the resources.

6. <u>FEASIBILITY PLAN FORMULATION AND SELECTION</u>.

Within the Corps' Civil Works Program, the formulation and evaluation of alternative plans to meet restoration objectives is conducted using an ecosystem approach with a watershed focus. This study is specifically focused on four sites that provide a high potential for environmental restoration success. Although flood damage reduction is an authorized purpose of this study, there are no specific intents to increase the size of the flood damage reduction project. There may be small incidental improvements, however, related to environmental restoration efforts.

The ecosystem approach consists of protecting or restoring the structure and function of an ecosystem, or parts thereof (four specific sites), recognizing that all components are interrelated.

Projects are conceived in a comprehensive, holistic context, considering aquatic, wetland, and terrestrial complexes to provide the potential for long-term survival as functioning systems.

Rather than maximizing habitat benefits for a single species or a resource commodity (*i.e.*, game, fish, and birds), ecosystem restoration planning will consider the roles of plant and animal species populations and their habitats in the larger context of community and ecosystem frameworks. An ecological community Habitat Suitability Index model will be developed to measure the output of restoration alternatives.

A list of some of the structural and functional characteristics of ecosystems is provided on plate 2. These characteristics illustrate the range of considerations that may be necessary to effectively identify ecosystem problems, develop restoration objectives, and formulate applicable restoration measures.

The watershed focus for ecosystem restoration maintains the Corps' traditional mandate for water and related land resource activities. Water is a key element in shaping the structure and function of ecosystems. The impact of Corps activities on water in the project reach, and the related consequences on ecological resources, will be examined. Conversely, the impact of a watershed's existing water quantity and quality on ecological resources, and the potential restoration features within that watershed, will need to be identified.

By focusing on the Upper Snake River ecosystem structure, the Corps' interdisciplinary planning team (including the Sponsor) will identify parameters that are altering water quantity or quality and adversely impacting the ecosystem, or parts thereof, within that watershed. Consideration must be given, during plan formulation, to those activities and conditions in the watershed that may influence the success, persistence, and resilience of the restoration proposal, even though they may exist outside of the study area. Hydrology and sediment transport are two key functions that must be investigated in order for this restoration effort to be successful. The operation and management of Jackson Lake Dam by the U.S. Bureau of Reclamation (BOR) is an important consideration in this study. Through collaborative efforts with BOR, it may be possible to improve the flow regime of the Snake River in the project area.

The site-specific objective of this proposed restoration report will require an understanding of the natural dynamic system. Critical needs include an inventory of baseline resource conditions along the upper Snake River, including both existing and historical hydrologic conditions; detailed evaluations of historical and existing riparian, wetland, and aquatic resources; and detailed geomorphology studies. Work will consist of providing detailed design and engineering of restoration measures formulated during the reconnaissance study, including the evaluation of combinations of restoration measures into comprehensive alternatives for the four site-specific areas of the study. Also included will be an evaluation of current conveyance capacities; evaluation of applicable laws, constraints, and social values placed on traditional and current uses of the Snake River system; and an assessment of the proposed restoration alternatives on O&M practices. Detailed plan evaluation will be undertaken during this phase to determine Federal interest.

The U.S. Water Resource Council's P&G, dated 1983, provides the instructions and rules for Federal water resource planning. The P&G requires that, in developing alternative plans, Federal planners should "include only increments that provide net National Economic Development (NED) benefits (for flood damage reduction, navigation, and other traditional benefit categories)...Increments that do not provide net NED benefits may be included...if they are cost effective." The Corps' guidance reflects this directive and requires an incremental cost analysis for recommended environmental restoration and mitigation plans.

Cost Effectiveness for Environmental Planning: Nine EASY Steps, October 1994, was developed by the Corps to assist planners conducting cost effectiveness and incremental cost analyses in planning for environmental restoration. Two analytical processes are conducted to meet these requirements in environmental planning. First, a cost effectiveness analysis is conducted to ensure that the least-cost solution is identified for each possible level of environmental output. Subsequent incremental cost analysis of the least-cost solutions is conducted to reveal changes in costs for increasing levels of environmental outputs. In the absence of a common measurement unit for comparing the non-monetary benefits with the monetary costs of environmental plans, cost effectiveness and incremental cost analyses are valuable tools that assist in decision making.

Alternative comprehensive plans will also be developed. These plans will vary in size, scope, and cost. A comparison of alternatives, based upon associated costs and benefits, will be made. Collaborative efforts with the Sponsor, the public, the community, and private property owners will select final plans.

7. REPORT PREPARATION.

Following public scoping of alternatives, a draft Feasibility Report and Environmental Impact Statement (EIS) will be prepared, with opportunity provided for a public review and comment. Following review and clearance of the Feasibility Report and EIS, it will be finalized. It will be complete with appendixes that provide details on coordination activities; engineering, real estate, plan formulation, environmental and economic studies; and a preliminary financing plan. A draft Project Cooperation Agreement (PCA) will be prepared to accompany the report. The Sponsor will be required to furnish a letter of intent indicating their willingness to cooperate in the recommended plan and provide the local assurances, in accordance with the draft PCA.

8. REVIEW, SUPPORT, AND REVISIONS.

Comments received on the draft Feasibility Report and EIS will be addressed, and any revisions necessary for the final report will be completed. The Sponsor will be afforded the opportunity to participate in all additional significant rewriting, documentation, analysis, or reformulation as a result of HQUSACE-level review. A "Review Support" work item (in the amount of approximately $50,000) will cover expenditures for any such activities. Should costs be incurred beyond the Review Support, the FCSA will be modified to provide for 50/50 cost

sharing of any additional costs. Any costs relating to the Feasibility Report incurred following the completion of the Feasibility Phase, with the exception of review support activities, will be cost shared in accordance with the PCA.

9. FEASIBILITY STUDY COORDINATION.

a. Study Management Structure.

The study will be managed by the following five groups, at the appropriate level, throughout all phases of the study:

- HQUSACE Project Review Board (PRB)
- CENPD PRB
- CENPW PRB
- The Executive Committee
- The Study Management Team

The Sponsor will participate in both the Study Management Team and the Executive Committee.

The principal document used for reporting to the PRB's and the Executive Committee will be the Project Executive Summary (PES) report which is issued monthly.

The HQUSACE PRB will be chaired by the Director of Civil Works, or their designee, and will include the Chiefs of the functional elements. The HQUSACE PRB will facilitate the resolution of major study issues, concerns, or problems through the Corps' functional channels, and make recommendations to the Director of Engineering, CENPD, and the Sponsor, as part of intensive management. The HQUSACE PRB will also approve changes in major milestones and significant cost increases, in accordance with Engineering Regulation (ER) 5-7-1, *Project Management*.

The CENPD PRB will be chaired by the Division Commander or their designee and will include the Chiefs of the functional elements whose functions are integral to the role of the Division in civil works projects. Since the Feasibility Report is a CENPW Planning Division product, the Planning Division will be used to guide technical and policy issues through its chain of command up to HQUSACE. The CENPD PRB will review monthly PES reports for compliance with the PSP and provide comments to CENPW. The CENPD PRB will facilitate resolution or elevate to the CENPD Commander or higher authority major issues raised during the study and take appropriate action on the Schedule and Cost Change Report (SACCR), in accordance with ER 5-7-1, *Project Management*.

b. The Executive Committee and Study Management Team.

The Feasibility Studies will be managed by an Executive Committee and a Study Management Team as provided in the Feasibility Cost Share Agreement (FCSA). The Executive Committee will oversee the overall study conduct, management, and Corps policy. The committee membership includes the CENPW District Engineer, Chief of Planning (or designee), and Chief of Operations. It will also include a designated Teton County Commissioner and a designated Teton County Natural Resource District Board Member who will be partners with the CENPW representatives. The District Engineer and the Teton County Commissioner will co-chair the committee. The Study Management Team will include the CENPW Planning Study Manager, the Study Manager from the Sponsor, and other key study team members. The Study Management Team will oversee studies to ensure the establishment of desired mutual roles, interests, and study objectives. The Study Management Team will implement overall direction of the study provided by the Executive Management committee and ensure that Corps' policy and the breakdown of tasks provided by the PSP are followed. In addition, the Study Management Team will ensure that the study schedule and budget are maintained, that sound technical judgment is followed, and a multidisciplinary approach and decisions are made in accordance with applicable guidelines and policies. The Study Management Team will ensure that adequate input to the study process is received from all appropriate Federal, State, and local agencies; interested organizations; and individuals.

c. Quality Management Strategy.

The goal of the quality management strategy is to achieve high quality products and output from the study. The measurement of quality will be made in terms of specific criteria. The criteria will be kept to a minimum to ensure quality products and reduce frivolous quality management exercises. The output from the study will consist of the draft and final technical reports, the Feasibility Report, the draft and final EIS, technical appendixes (Environmental, Hydrology, Engineering, Economics, and Real Estate), and the Project Management Plan (PMP). Quality will be achieved through feed-back reviews of technical reports, the Feasibility Report, EIS, and technical appendixes throughout the study.

The quality of these products will be the responsibility of the team members and their immediate supervisors and the study team managers (both the CENPW and the Sponsor). The quality will be measured by team members, with quality review by the Steering Committee, and comments provided through the public involvement process. Team members will review draft office reports resulting from various tasks and provide comments during team meetings. The Steering Committee will provide comments following quarterly review meetings. The public involvement program will provide comments on the draft and final EIS and the draft and final Feasibility Report. A technical review team will provide an independent review of all technical documents. Appendix A provides a quality control plan for technical review.

10. TASKS AND RESPONSIBILITIES.

The Feasibility Study will evaluate the ecosystem restoration objective and focus on formulation through the reasonable maximization of environmental outputs. The final stages will focus on the development of definitive plan selection. It will include the following study tasks: study management; hydrologic analyses; geomorphic analyses; geotechnical evaluations; geospatial data management; engineering evaluations; design; cost estimation; economic and institutional analyses; real estate evaluations; riparian and wetland ecology investigations; Clean Water Act compliance; aquatic ecology investigations; endangered species investigations; Endangered Species Act (ESA) compliance; cultural resource compliance; public involvement; plan formulation; report preparation; project management; and report review (see plate 3). Work Order Requests (WOR's) will be issued by the Corps' Study Manager detailing specific study tasks, funding, milestones, form, and detail of the expected product, as identified in this PSP. The Study Manager will review all contracts for work to be accomplished by others.

The following paragraphs contain a description of the major Feasibility Study tasks, as well as the responsibilities for the accomplishment of those tasks. The JHER PSP is comprehensive in scope, having sufficient information to produce the products and define the level of detail necessary for accomplishing each task. As referenced in the FCSA, Article I, the item "negotiated cost" is the fixed fee for a work item to be accomplished by the Sponsor as in-kind service. The term "in-kind" refers to those tasks completed by the Sponsor in substitution for a cash contribution. Technical studies performed by the Sponsor will be reviewed for conformance to the Corps' standards and study needs.

a. Study Management.

This task will be conducted by the CENPW and the Sponsor (see plate 4). Tasks common to the Corps and the Sponsor include the preparation of correspondence, inter-organization coordination, public involvement, and the overall leadership of the study effort. Periodic meetings will be held between the Corps and the Sponsor to coordinate and monitor in-kind services. Monthly status reports covering selected financial and performance measurements will be provided by the Corps' Project Manager. Study Management Team meetings will be scheduled on a monthly basis.

The CENPW task includes managing all activities, in accordance with the current guidelines outlined in ER 1105-2-100, *Guidance for Conducting Civil Works Planning Studies*; ER 5-7-1, *Project Management;* and draft EC 1105-2-206, *Environmental Restoration Planning Guidance.* This includes overall study direction; study scheduling; providing detailed information for the task to be conducted; issuing WOR's; establishing and monitoring study milestones; developing task activities, task schedules, critical path milestones, and funding schedules; directing, monitoring, and modifying assigned task items and funds; and providing dispute resolution.

The CENPW Study Manager will ensure that all required tasks are performed for the production of a quality Feasibility Report. The Study Manager will maintain coordination with

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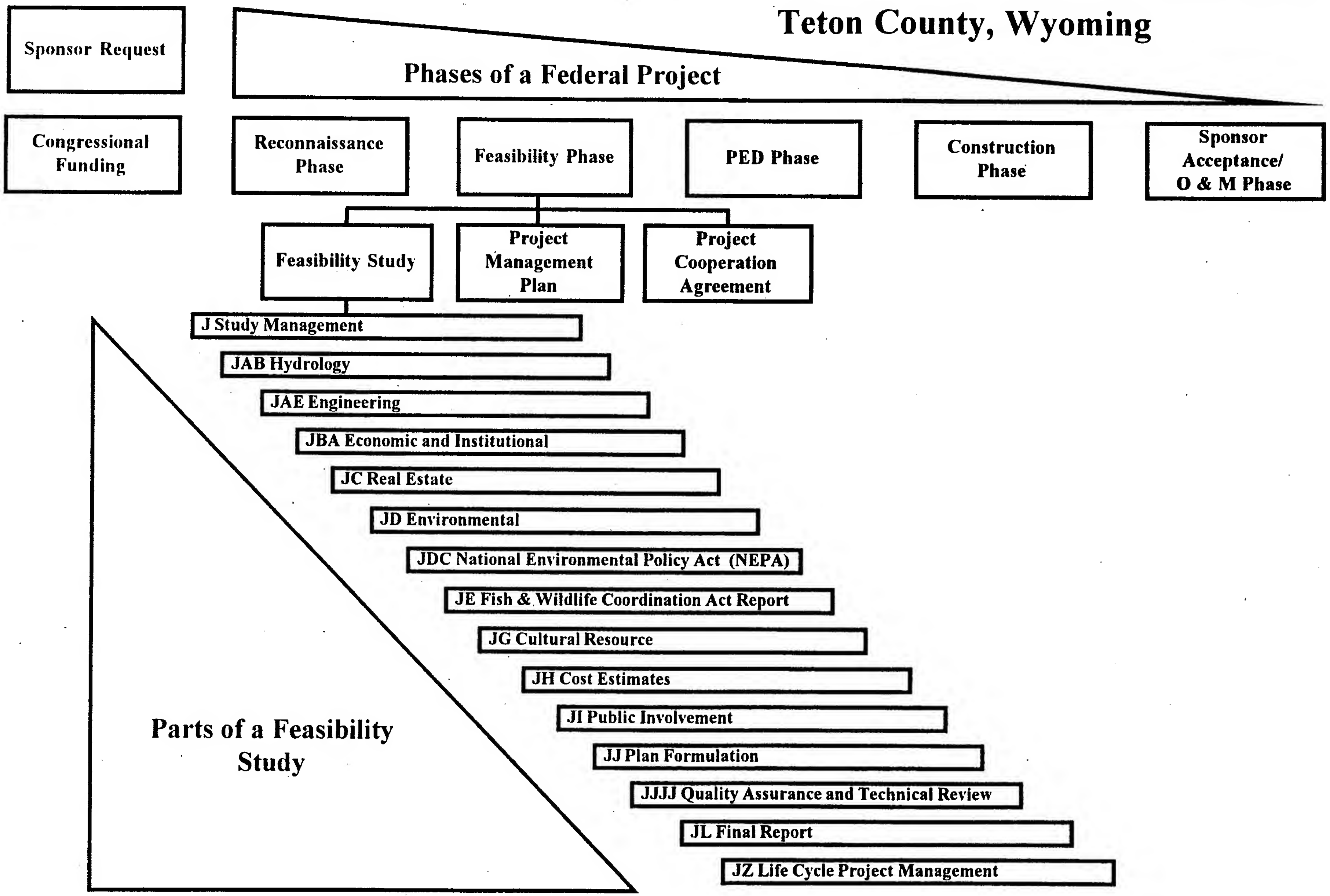

Plate 3 - Phases of a Federal Project Work Breakdown Diagram

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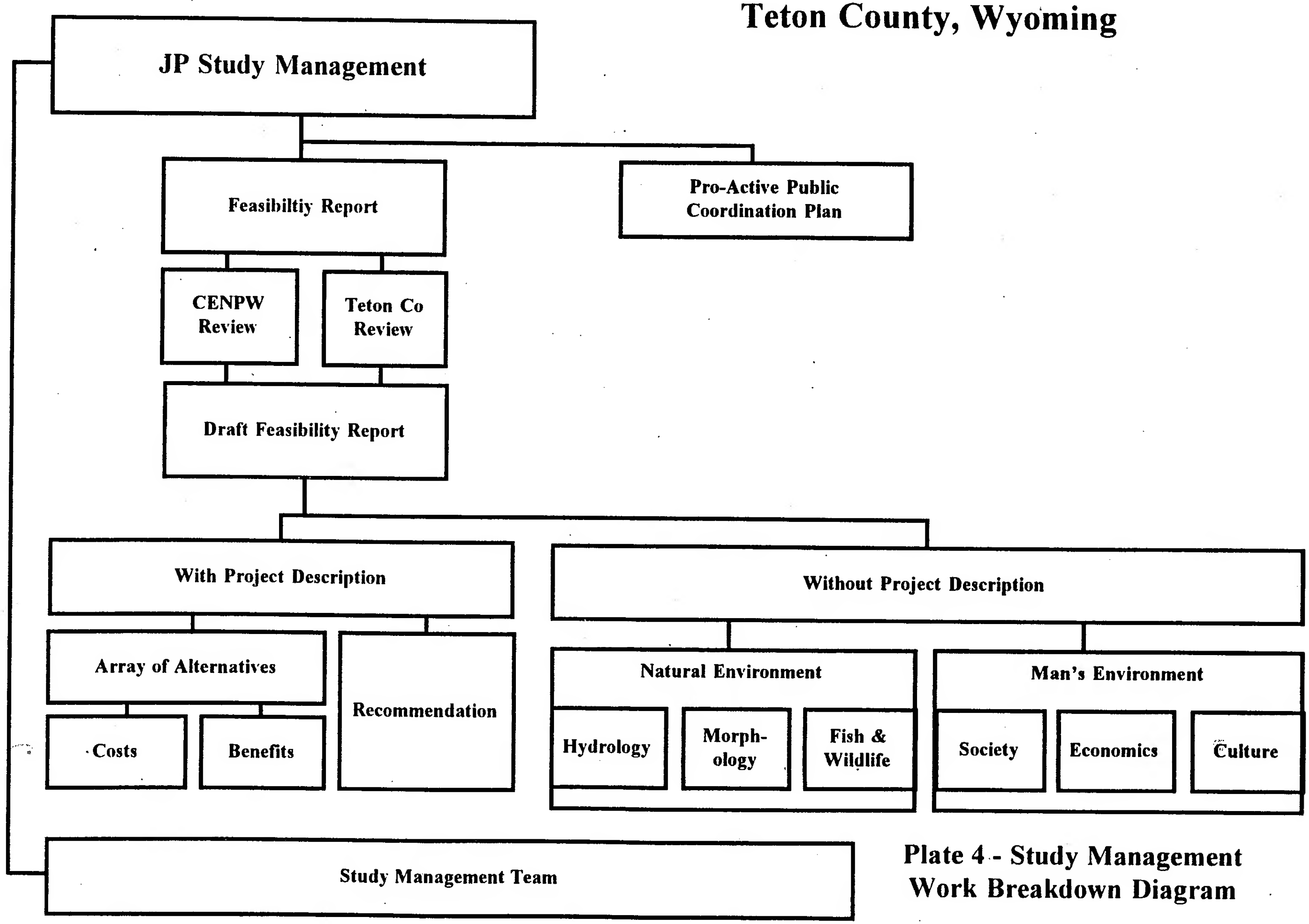

Plate 4 - Study Management Work Breakdown Diagram

the multidisciplinary study teams to ensure effective and timely decision making. The Study Manager will also monitor the scope and progress of study activities to maintain the study within budget and on schedule; and will take necessary action to resolve potential scope, schedule, cost/funding, and policy concerns. The Study Manager will coordinate with the Project Manager.

The Sponsor task entails performing the study management needed to complete work items during the Feasibility Study. Study management includes coordinating activities with the Corps on in-kind services and management of the performance of those activities. Study management includes the management of study tasks, study scheduling, budget preparation, and preparation of funding status reports.

b. Hydrologic.

This task will be performed by CENPW, with substantial assistance from the Sponsor, both in the collection of data and in review and coordination (see plate 5). Study tasks include a review of basin hydrology, with particular emphasis on Jackson Dam operation; a study of fluvial geomorphology within the study reach; an overall survey of the study area to identify restoration opportunities and methods; and a detailed hydraulic analysis of several specific locations where restoration opportunities appear to be the most favorable.

The hydrology review will consist of updating existing peak discharge frequencies, assembling flow data on secondary channels and tributary streams, and an analysis of Jackson Dam operational limits and the resulting effect of flood peaks and flow duration downstream. Closely related to this element will be a groundwater study, administered by Teton County, which will establish the relationship between surface flow and groundwater levels.

The geomorphology portion of the study will explore how the valley slope, rock formations, alluvial materials, and river discharge affect channel stability; as well as how these factors will impact efforts to reestablish vegetation and aquatic habitat within the influence of the main channel of the Snake River. This study will produce maps indicating channel bed materials and armoring, the distribution of erosion and deposition, and the history of channel movement.

Drawing from knowledge obtained from the hydrology and geomorphology portions of the study, CENPW, Hydrology Branch, will work jointly with Environmental Resources Branch to develop maps covering the four sites that will indicate opportunities and locations for habitat restoration. Channel and island stabilization, channel modification, and possible restoration of aquatic habitat in the riparian zone behind the levees will be included.

Four of the most favorable sites, identified on plates 1-1 through 1-12, will be evaluated in greater detail. Hydrology tasks will include backwater studies to determine channel capacity and levee profile requirements, sediment transport, erosion and deposition, and the development of risk and uncertainty data associated with flooding and erosional attack.

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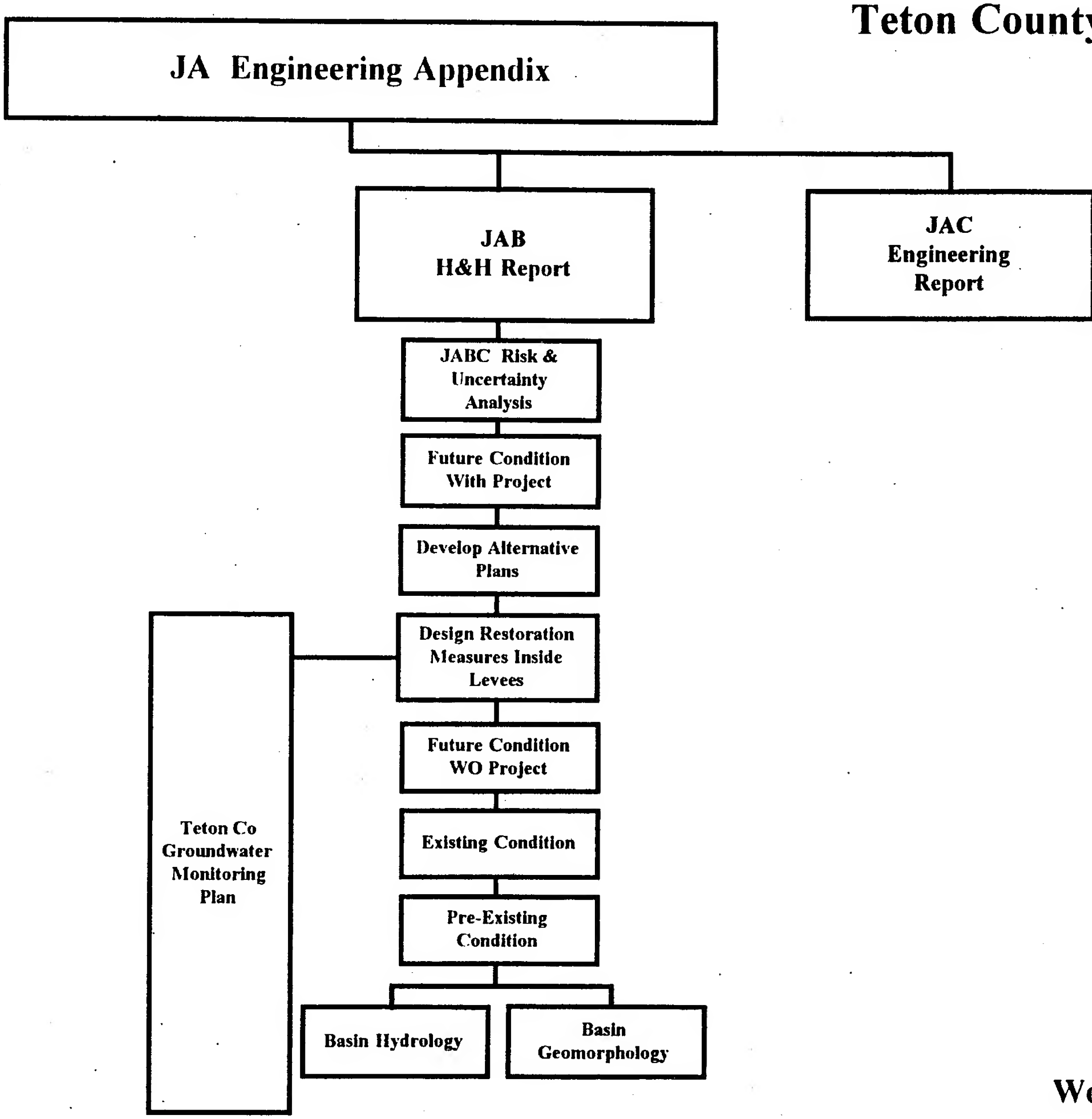

**Plate 5 - Hydrologic
Work Breakdown Diagram**

c. Engineering.

The Corps will perform the engineering portion of this study (see plate 6).

Site visits will allow the designers to become familiar with field conditions. Explorations, consisting of test pits dug with a backhoe, are needed to determine foundation conditions. Explorations will be called for as the individual options are studied and designed. Each option will include the foundation conditions for that site. A foundation report will be prepared that covers the options at four sites.

An Engineering Appendix will be prepared that will show the different options analyzed. The options will be limited, both in number and scope, to those shown in the cost breakdown. The level of study will develop designs with sufficient detail for cost estimate and comparison studies. It is assumed that a riprap source is available. Determining the riprap source is part of an operation and maintenance EIS process and will be funded by other sources than this study.

Potential sites will be examined for hazardous and toxic waste. This will include a field reconnaissance of the sites, literature review, and coordination with the U.S. Environmental Protection Agency. A report will be prepared and will be included in the EIS.

Cost estimates will be prepared for each option studied. A baseline feasibility-level estimate will be developed for the selected plan. The baseline estimate will include both Federal and non-Federal costs for construction, real estate, engineering and design, construction management, and life cycle project management, in the Microcomputer Aided Cost Estimating System (MCACES) Code of Accounts format.

d. Economic and Institutional.

This task will be performed by the Corps and the Sponsor (see plate 7). It will include a sensitivity analysis, an environmental restoration incremental analysis study, and an analysis of the Sponsor's Financial Plan and ability to pay.

Environmental restoration alternatives for restoring riverine, wetland and riparian habitats will be analyzed. The most effective alternative will be evaluated incrementally to establish the most effective level of investment in accordance with *Cost Effectiveness for Environmental Planning: Nine EASY Steps*, October 1994. Given selected low energy and high energy structural alternatives (furnished by Engineering Division) and Habitat Suitability Indices (furnished by Environmental Resources Branch), the economist will evaluate the plan that is most incrementally effective in terms of restoring (at an attainable goal) and maintaining the environment indigenous to the area.

A sensitivity analysis will be conducted using the key variables involving risk to project costs and benefits. The sensitivity analysis will be integrated with the incremental analysis program to determine an expected level of cost effectiveness at a given level of costs and output

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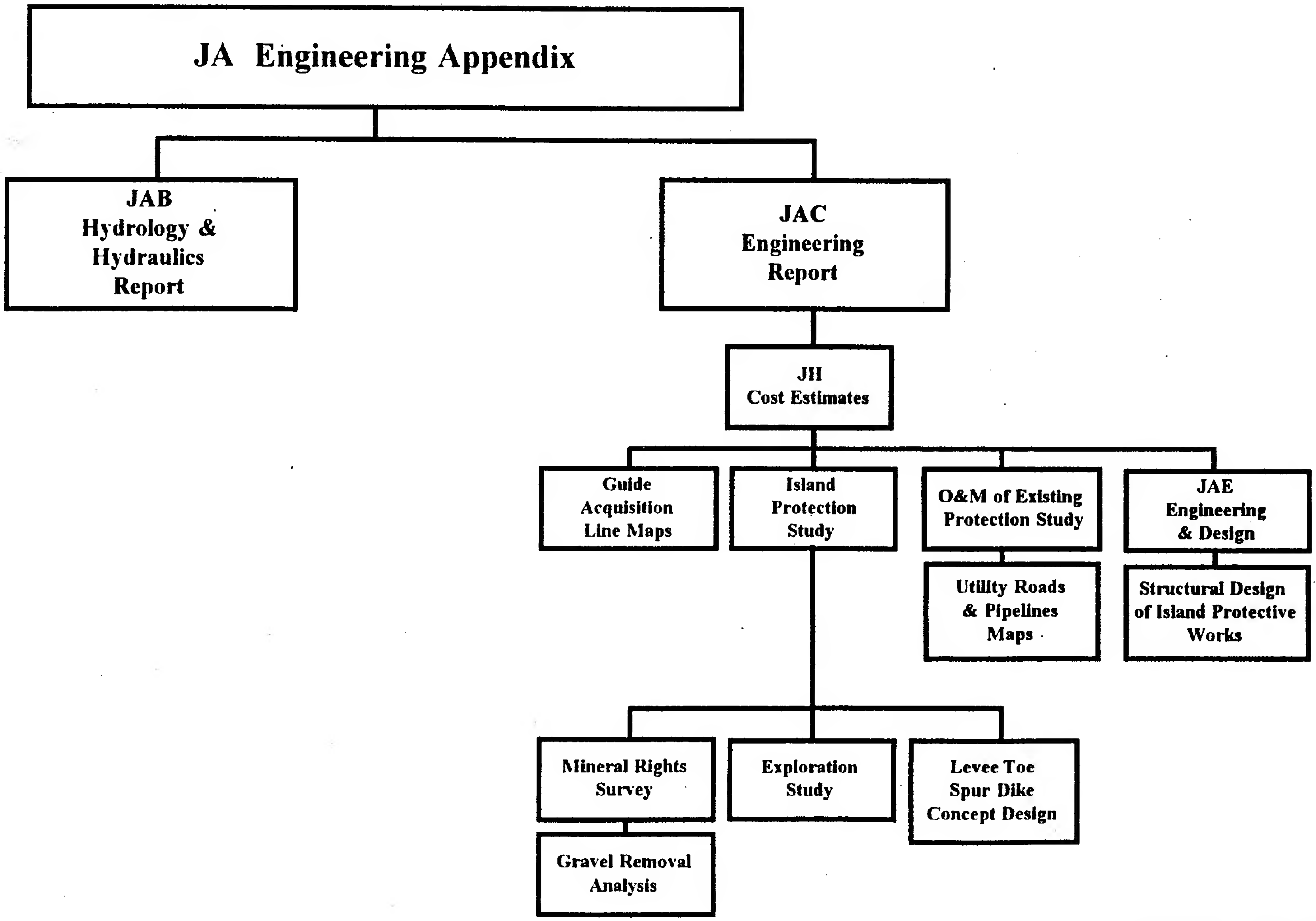

Plate 6 - Engineering Work Breakdown Diagram

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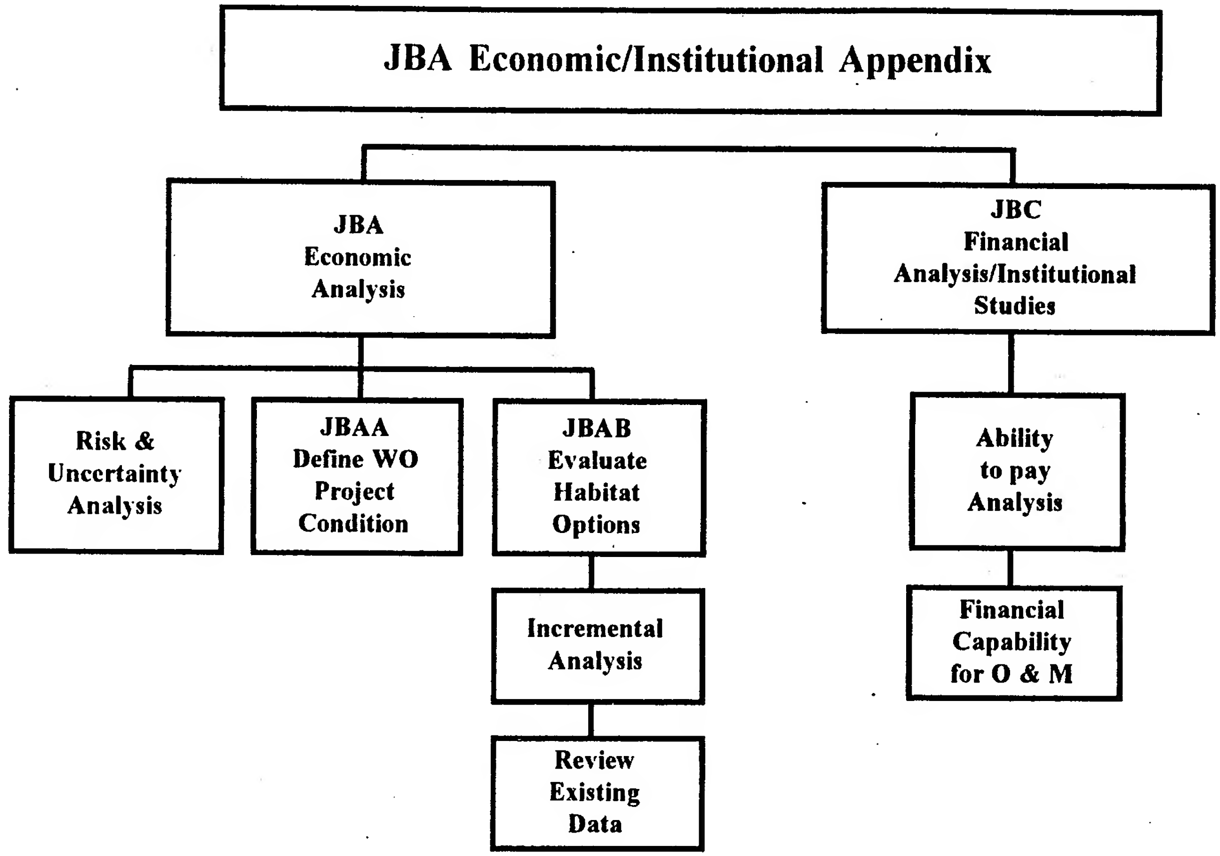

Plate 7 - Economic/Institutional Work Breakdown Diagram

as well as an adjusted value due to the variability of construction costs, schedules, and environmental outputs expected.

Institutional studies will also be included in the economic analysis and will be performed by the Corps and the Sponsor. These studies consist primarily of determining the financial and legal arrangements required to implement the recommended plan, including the method of financing the projects.

The Sponsor will prepare a financing plan and an accompanying statement of financial capacity (including a Statement of Revenues and a Statement of Funds for the last 3 years). The financing plan should include a schedule of the sources and uses (cash flow) of local government income, current local indebtedness, operating expenses, expenditures, trends in assessed values, and other financial data. The statement of financial capability should provide evidence of the Sponsor's authority to utilize the identified sources of income.

e. <u>Real Estate</u>.

This task will be performed by the Sponsor (see plate 8) with Corps Real Estate Review. The study input will include the preparation of preliminary Real Estate Cost Estimates for an alternative environmental restoration plan for right-of-way requirements, participation in pre-project cooperation agreement activities, preparation of the Real Estate Supplement for inclusion in the Feasibility Report, preparation of a Gross Appraisal Report, preparation of the Baseline Cost Estimate for Real Estate (prepared in the Code of Accounts format), and preparation of the scopes of tasks outlining real estate input to the PMP. This task includes securing rights of entry for cultural, environmental, survey, geotechnical, and other needs.

The real estate portion of this study will include a gross appraisal, detailing value of project lands. If necessary, it will also include relocation costs in accordance with Public Law (PL) 91-646, along with the determination of necessary easements, rights-of-way, *etc.* Rights of entry will be required for environmental, cultural, and engineering studies. The identification of ownership and detailed real estate maps will be developed based on project design requirements. A real estate supplement will be prepared that identifies all real estate requirements for the project and provides a baseline cost estimate and acquisition schedule.

All real estate tasks will be performed in accordance with ER 405-1-12, *Real Estate Handbook*. All costs, including acquisition and administrative costs, will be identified in the MCACES Code of Accounts format, as required by, *Civil Works Project Cost Estimating - Code of Accounts*.

The real estate section of the appendix will provide a summarization of all tasks performed in providing the above information. This task will include the preparation of materials, including text and plates, for inclusion in the appendix; performing required investigations; coordination of the writing of the real estate section of the appendix; in-house report review; response to comments; and support to other technical and nontechnical elements during the study phase.

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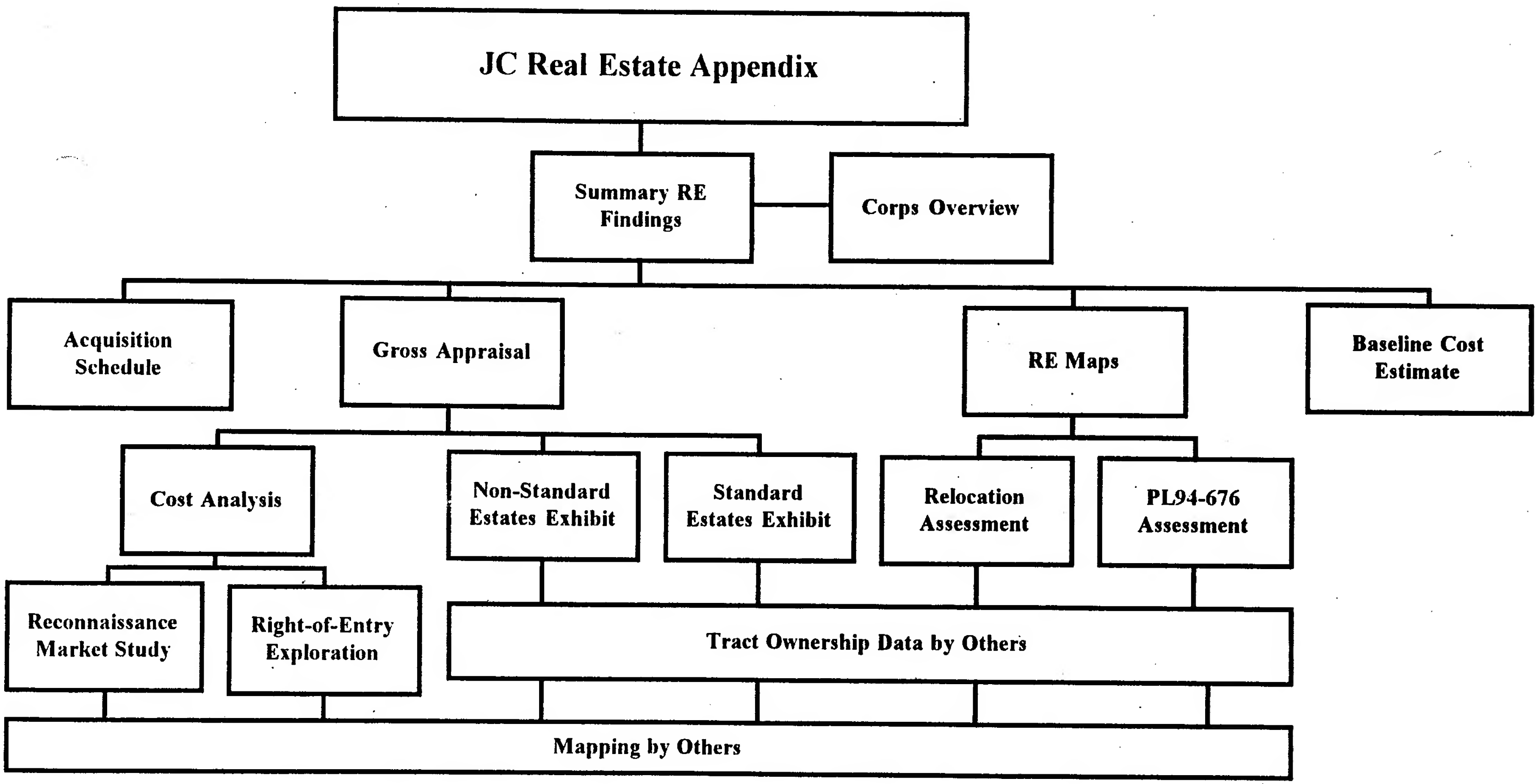

Plate 8 - Real Estate
Work Breakdown Diagram

f. Environmental.

(1) The EIS.

An EIS will be prepared by the Corps with substantial involvement by the Sponsor (see plate 9) in accordance with NEPA and Council of Environmental Quality guidance.

The Corps will prepare both the draft and the final EIS. The EIS will evaluate the environmental effects of the alternative restoration features and will be coordinated with the Federal, State, and local governments and agencies, as well as with interested groups and individuals. Environmental impact assessment tasks include all activities required to comply with NEPA. Activities include: Literature searches and review of existing reports and field surveys to establish environmental base-line conditions; identification of future "without-project" conditions; determination of impacts of the alternatives; fish and wildlife coordination; ecosystem evaluation; development and preparation of all appropriate NEPA documents; in-house report review; response to comments; and support to the Study Manager and others during the assessment.

The scope of the restoration measures for the riverine and palustrine ecosystem and other resources will be described. A monitoring plan will be developed to record the success of restoration measures. In addition, environmental benefits will be evaluated for each of the alternatives.

Cultural resource compliance will be included in the EIS, as well as socioeconomic studies, to determine any social impacts of the selected plan.

Pursuant to the Fish and Wildlife Coordination Act, a Coordination Act Report will be prepared by USFWS in coordination with the Corps.

A section 404(b)(1) evaluation of water quality impacts will be developed and coordinated with State and Federal water quality agencies to ensure adequate consideration has been given to water quality and in order to acquire water quality certification.

Requirements of the ESA of 1973, as amended, will be completed during the Feasibility Study, including a biological assessment. Formal consultation with USFWS will be conducted, if necessary.

Adherence with Executive Order 11988 for Floodplain Management, Executive Order 11990 for Protection of Wetlands, and other pertinent environmental statutes and regulations will be noted in the EIS.

(2) Ecological Analyses.

The Corps will conduct a number of investigations and studies in conjunction with contractors and other agencies (see plate 9). These efforts will establish the necessary baseline knowledge, or refine the current knowledge of the ecology of the project area, in order to define

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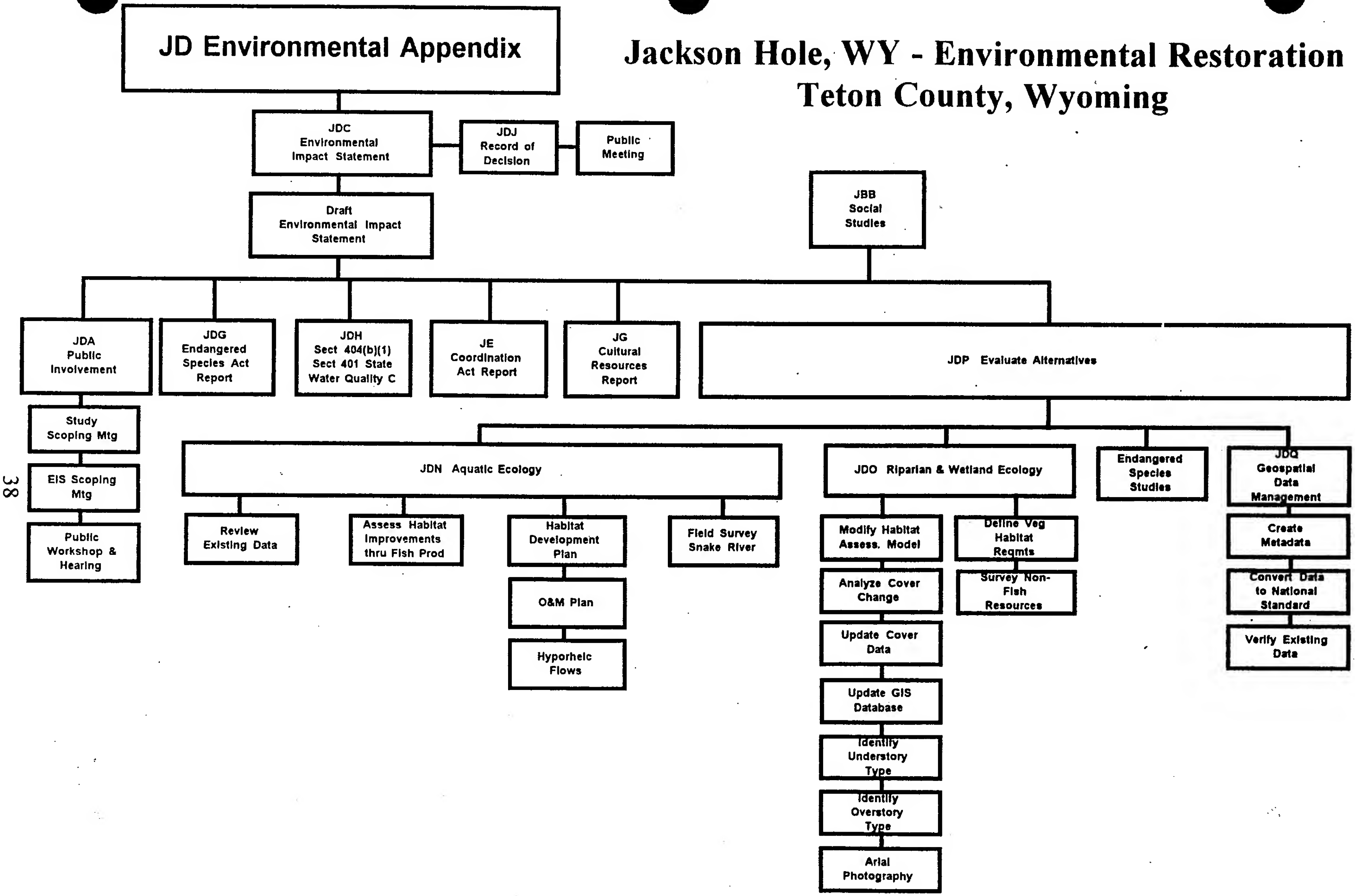

Plate 9 - Environmental Work Breakdown Diagram

"future without project conditions" and "future with project conditions." The knowledge gained will also be used to assess the impacts and benefits associated with the various alternatives, as well as to analyze incremental developments with the greatest benefit and the least cost.

The Corps will utilize a Tri-Agency Team approach to revise an existing habitat community assessment model to conduct the aforementioned analyses. The team will consist of the Wyoming Game and Fish Department, USFWS, and the Corps. The incorporation of other agencies and local representation will occur at points in model selection to ensure the best review of ecosystem principles and needs, as applies to the Jackson Hole riverine and palustrine ecosystem.

The study does not propose to conduct any quantitative recreational impact studies. Currently, the only potential impacts on the river system are ingress and egress to the river (boat launches), camping, and fish quantity and quality. The following address each of those concerns.

(a) There are only two sites, the Moose and Wilson Bridge launch sites which provide access to the river and have the potential to impact the proposed project area. A 1990 report filed by the Wyoming Game and Fish Jackson Field Office indicated that during the summer months the Wilson Bridge site experienced 2,313 user days by fishermen using the upper stretch and 1,804 user days on the lower end. While a precise count for 1995 is not currently available, all qualitative indications suggest that the site experienced the same or a slightly higher level of use than in 1990.

(b) Camping on islands and on shore sites is prohibited by the settlement of the lawsuit between the Bureau of Land Management (BLM) and landowners adjacent to the Snake River. The settlement gave control of land above the normal water line to the landowners. With the landowners in control of how the land is used in the proposed project reach, many recreational restrictions are observed. Camping is one of the recreational uses which is prohibited in all but one or two sites. These sites are of limited public knowledge and, therefore, are not used. Proposed project outputs will not change the off water recreational use in the area.

(c) Controls on the fisheries population in the proposed project area have been put in place by the Wyoming Game and Fish Department through the use of slot limits. The current limit is three fish in possession with only one fish exceeding 12 inches. The environmental output "fisheries enhancement" would not indirectly lead to over-fishing due to the slot limit. The Wyoming Game and Fish Department also has regulations that control activities in the immediate vicinity of Bald Eagle nests along the proposed project reach. Proposed project outputs will not affect these regulations.

The USFWS will assist in defining the impacts and shaping possible alternatives to maximize benefits and avoid conflicting resource enhancement

All Corps activities include coordination with USFWS and the Wyoming Game and Fish Department, in-house report review, response to comments, and support to the Study Manager and others.

g. Cultural Resource Compliance.

This task will be performed by the Corps (see plate 9). All investigations and assessments will be performed in accordance with the National Historic Preservation Act (NHPA) of 1966 § 106, as amended; and the Archaeological and Historical Preservation Act (AHPA) of 1974. Close coordination will be maintained with the State Historical Protection Office (SHPO).

In consultation with the SHPO, the Corps will conduct sufficient archival and field surveys to identify cultural sites within the study's Area of Potential Effect (APE) and will evaluate the eligibility of all cultural sites for the National Register of Historic Places. A detailed report will be prepared that will describe all cultural resources within the APE and assess the impacts of alternatives on these resources. The report will also describe the range of additional future preservation efforts, if required, and the associated costs of these studies.

If alternative features are found that will have an effect on sites eligible for the National Register of Historical Places, the Corps will proceed with further consultation with the SHPO and will afford the Advisory Council on Historic Preservation (ACHP) and other interested parties an opportunity to comment. If necessary, the Corps may enter into a Memorandum of Agreement with the SHPO, ACHP, and Sponsor to stipulate ways to avoid or reduce the effects of project alternatives on cultural resources. Preservation or mitigation of cultural resources will be considered in more detail for the plan recommended for construction in any advanced planning for the project.

h. Public Involvement.

This task will be performed by both the Corps and the Sponsor (see plate 10). It primarily consists of coordinating the study and results with the public; conducting public meetings and workshops; and responding to inquiries. The public meetings will include a scoping workshop at the beginning of the study (EIS scoping, in compliance with the NEPA) and a final meeting after the draft Feasibility Report and EIS are distributed for public review. Also included is the preparation of a public involvement plan to guide public involvement activities. News releases and fact sheets will be provided at appropriate times throughout the study. The Corps recognizes that the success of this study is largely dependent on the cooperation of private property owners. Only through the involvement of private property owners can the overriding desire of the public for environmental restoration and the conservation of natural resources be realized. Both the Corps and the Sponsor will seek the concerns and suggestions of private property owners on a "face-to-face" basis.

The Sponsor (with CENPW involvement) will prepare a proactive public involvement plan, be responsible for hosting public meetings, and provide documentation. This task includes arranging for accommodations, inviting the public, maintaining a mailing list of property owners and local interested parties, and printing and distributing announcements. The Sponsor will maintain close contact with the media and promote awareness events.

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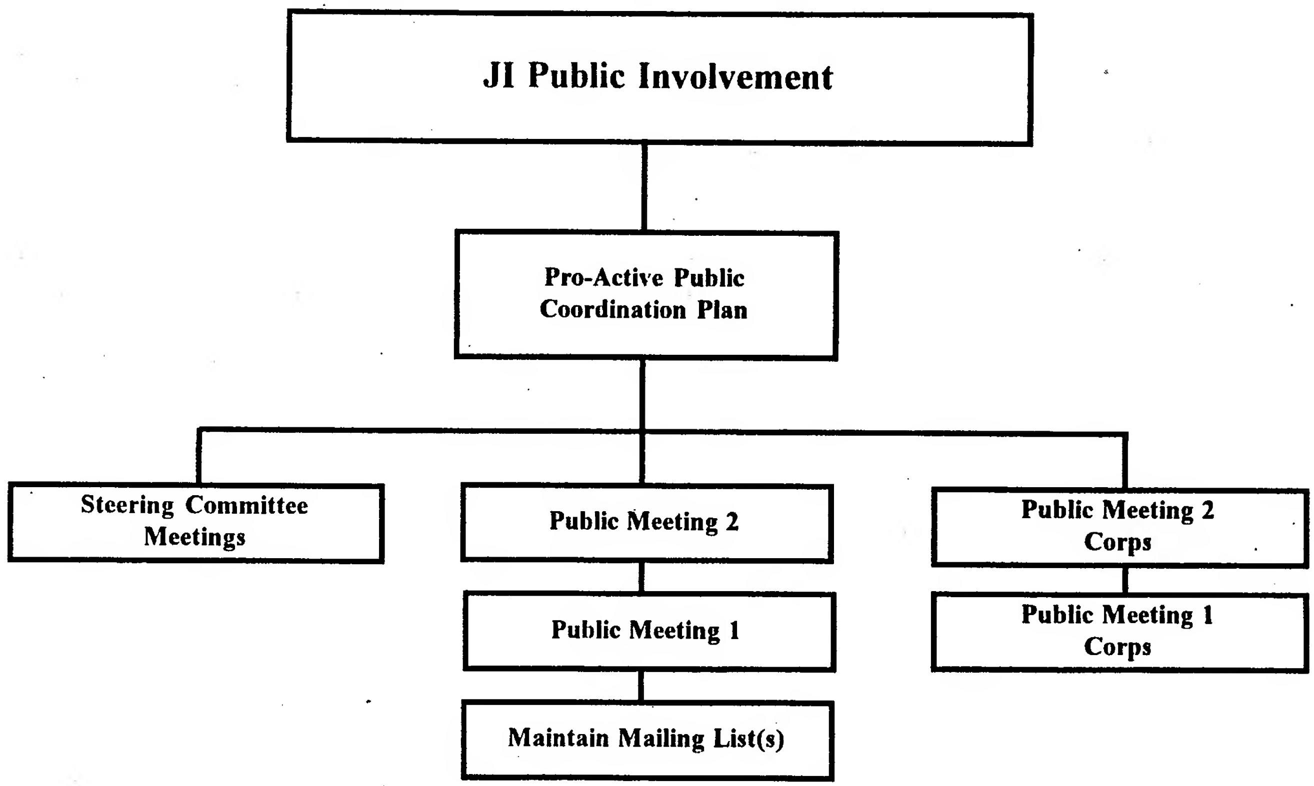

Plate 10 - Public Involvement Work Breakdown Diagram

i. <u>Plan Formulation</u>.

This task will be performed by the CENPW and the Sponsor (see plate 11).

Plan formulation will be in accordance with ER 1105-2-100, *Guidance for Conducting Civil Works Planning Studies*; EC 1105-2-206, *Environmental Restoration Planning Guidance*; P&G; NEPA, and other pertinent engineering, environmental, and economic guidance and regulations. Plan formulation will identify restoration measures for Feasibility Phase studies and develop the final alternatives.

Plan formulation also includes reviewing and refining the plans selected for study during the Feasibility Phase, other plans developed during the course of study, and developing required plans (the "no action" plan and various non-structural plans). This task includes identifying the final plan and considering any environmental and social impacts, as well as the views of the Sponsor and the public. Plan formulation will utilize risk and uncertainty analytical methodology. The costs and benefits associated with each restoration plan will be determined, and NED net benefit trade-offs will be identified. Plan formulation includes: Application of engineering, economic, environmental, and other criteria to the specific problems, needs, and constraints of the study area; and analyses and development of various methods, measures, and plans; and their contributions to, and effectiveness in addressing the specific problems. It is an iterative process with constant review, reformulation, and public input. Critical to the process of plan formulation will be the development of the "without-project condition" as a basis for comparison and evaluation of the alternatives.

The Sponsor will review and coordinate on the formulation of <u>all</u> alternatives and plans for detailed study.

j. <u>Report Preparation</u>.

This task will be performed by the CENPW with input from the Sponsor. The task will include the collection and assembly of pertinent data, writing, editing, typing, drafting, reviewing, revising, reproducing, and distributing the draft and final Feasibility Reports. This task includes all support work necessary from the initiation of the Feasibility Study through the Assistant Secretary of the Army's (ASA) Civil Works request to the Office of Management and Budget (OMB) regarding the Administration's views and policies.

k. <u>Feasibility Life Cycle Project Management</u>.

Life Cycle Project Management was established throughout the Corps in 1986 to enhance the performance of Corps projects and improve accountability. Life Cycle Project Management focuses on the successful completion and delivery of quality projects to customers, within an established budget and schedule.

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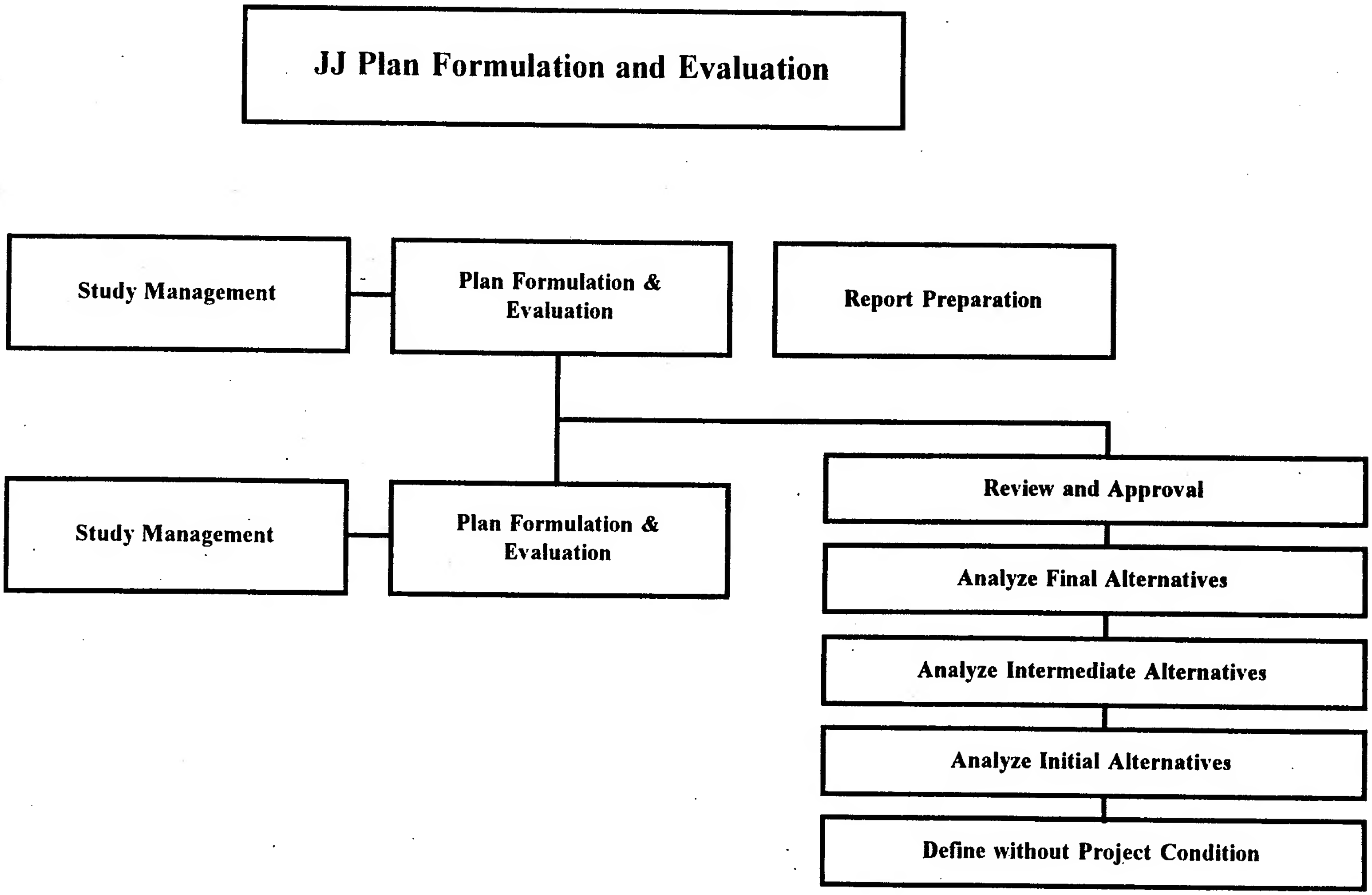

Plate 11 - Plan Formulation Work Breakdown Diagram

An individual project manager (PM) was assigned to the Jackson Hole, Wyoming, Environmental Restoration Project during the latter stages of the Reconnaissance Phase (see plate 12). The PM will have overall responsibility for the remaining phases under this civil works project. The following is a list of general functions that will be performed by CENPW's Programs and Project Management Division of which the PM is a part. Programs and Project Management Division implements Life Cycle Project Management on all CENPW projects. More specific tasks are included in the Feasibility Life Cycle Project Management section of appendix A, *Detailed Task Analyses*.

- During the Feasibility Phase, the PM will manage the study parameters (cost, budget, schedule, scope, and quality), as well as interface with those involved in the study process (Sponsor, functional elements, Government, and non-Government entities).

- The PM will be the primary point of contact with the Sponsor and within the Corps (but not only the point of contact, as the study manager and team will be required to do frequent coordination).

- The PM will coordinate with the Programs Management Branch which is responsible for the development of budget and schedules, execution of Congressional testimony, and the preparation of programmatic, multi-year budgets.

- The PM will manage the Feasibility Phase. The Feasibility Phase will generate three Level 3 products: Feasibility Report, PMP, and Draft PCA.

- The PM will coordinate closely with the Study Manager.

- The PM will be responsible for the development of the PMP.

In appendix A, *Detailed Task Analyses*, the costs for Life Cycle Project Management during the Feasibility Phase are defined as a Project Management Document and Coordination Product and spans the 4-year study. The PMP is another product that will be developed near the end of the Feasibility Phase. Its costs are shown separately in appendix A, *Detailed Task Analyses*. This PMP will guide the project through the Construction General Phase. The cost for each product includes Sponsor participation.

Jackson Hole, WY - Environmental Restoration
Teton County, Wyoming

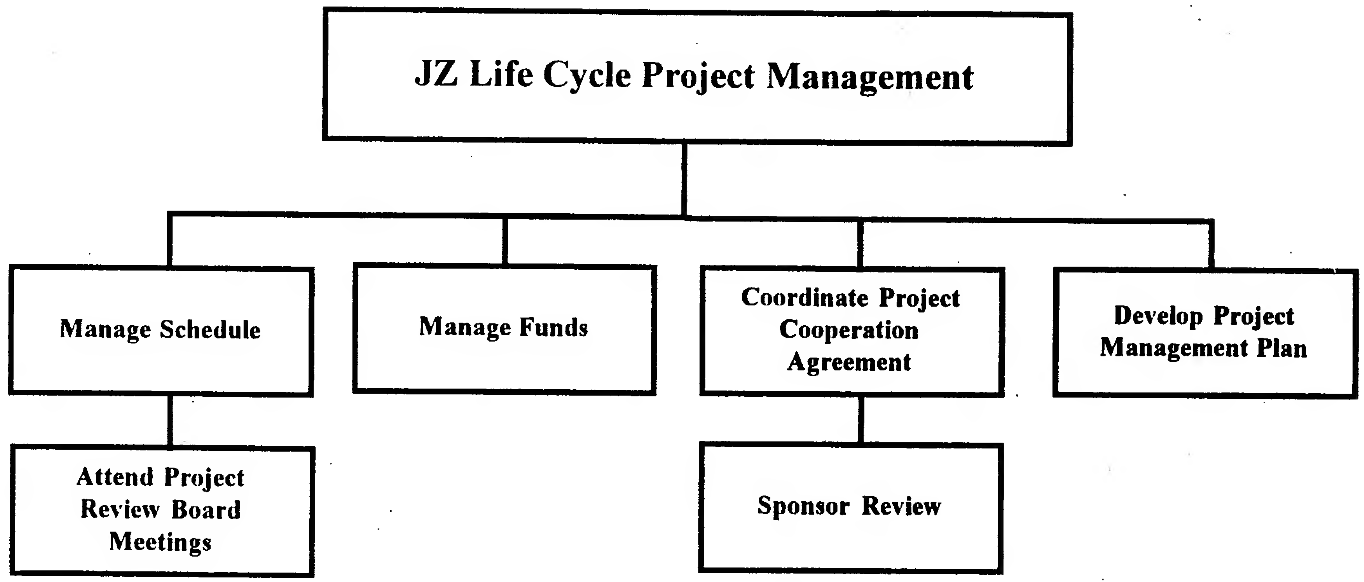

Plate 12 - Project Management Work Breakdown Diagram

11. FEASIBILITY STUDY COST ESTIMATE.

The Feasibility Study cost estimate for the Jackson Hole, Wyoming, Environmental Restoration Feasibility Study is $1,400,000 (see table 2). All Feasibility Phase study costs will be cost-shared between the Corps and the Sponsor on a 50/50 basis. Table 3 provides a Study Responsibility Matrix. Furthermore, the Sponsor will provide, at a minimum, half of its share as a cash contribution.

12. FEASIBILITY STUDY SCHEDULE.

The final Feasibility Report, with appendixes and EIS, is scheduled to be submitted to CENPD approximately 48 months after initiation of the Feasibility Study. The FCSA is scheduled to be signed prior to initiation of the study. The Division Engineer's issuance of the Public Notice ends the Feasibility Study and is scheduled to occur 1 month after the final Feasibility Report is submitted. The Feasibility Phase is completed when the final Feasibility Report is submitted to OMB.

13. COORDINATION BETWEEN THE CENPW AND THE SPONSOR.

The Executive Committee will meet at the signing of the FCSA, as well as periodically at public meetings, the Issue Resolution Conference, and the Feasibility Review Conference, to discuss project status and handle changes in study scope that would result in an increase in total study cost, major changes in study direction, or policy. The Study Management Team will meet approximately every 4 weeks but will meet more often during critical periods determined by the Study Manager.

Financial coordination will include quarterly financial statements composed of expenditures and obligations. The CENPW will also provide annual reports to the Sponsor, including Finance and Accounting (F&A) data base records. The Sponsor will provide to the CENPW, on an annual basis, similar finance and accounting data that will record cash expenditures and task-in-kind efforts. The first cost-sharing cash payment will be made to the CENPW on or about May 15, 1996, and others will be made prior to September 1 each year. The first payment will be made upon initiation of the study for the amount expected to be expended in the fiscal year. A final audit of the cost-sharing agreement and reconciliation of cash payment will be made at the conclusion of the study.

TABLE 2. BASELINE FEASIBILITY COST ESTIMATES

STUDY MANAGEMENT		
Corps In-House		$202,730
Sponsor		$69,179
	Subtotal	$271,909
HYDROLOGY AND HYDRAULIC STUDIES		
Corps In-House		$167,500
Sponsor		$44,320
	Subtotal	$211,820
GROUNDWATER		
Corps In-House		$0
Sponsor		$90,800
	Subtotal	$90,800
ENGINEERING AND DESIGN		
Corps In-House		$174,507
Sponsor		$4,000
	Subtotal	$178,507
ECONOMIC AND INSTITUTIONAL STUDIES		
Corps In-House		$34,150
Sponsor		$10,000
	Subtotal	$44,150
REAL ESTATE REQUIREMENTS		
Corps In-House		$9,600
Sponsor		$27,250
	Subtotal	$36,850
ENVIRONMENTAL STUDIES		
Corps In-House		$176,955
Sponsor		$16,400
	Subtotal	$193,355
PUBLIC INVOLVEMENT		
Corps In-House		$0
Sponsor		$18,500
	Subtotal	$18,500

PLAN FORMULATION AND EVALUATION		
Corps In-House		$19,620
Sponsor		$4,160
	Subtotal	$23,780
QUALITY CONTROL PROCESS AND TECHNICAL REVIEW		
Corps In-House		$14,000
Sponsor		$2,600
	Subtotal	$16,600
REPORT PREPARATION		
Corps In-House		$36,050
Sponsor		-0-
	Subtotal	$36,050
REVIEW SUPPORT AND REVISIONS		
Corps In-House		$37,060
Sponsor		$13,320
	Subtotal	$50,380
PROJECT MANAGEMENT		
Corps In-House		$84,097
Sponsor		$15,200
	Subtotal	$99,297
CONTINGENCIES		
Study Cost	Subtotal	$1,271,998
Contingency applied to the total study cost.	10 Percent	$127,200
GRAND TOTAL		**$1,399,198**

GRAND TOTAL SUMMARY		
Corps In-House		$956,269
Sponsor In-kind		$315,729
	Subtotal	$1,271,998
Contingencies		$127,200
GRAND TOTAL		**$1,399,198**

Jackson WY, Restoration
Study Responsibility Matrix - Table 3

			PL				EN									OUTSIDE NPW					
CWBS	TASK / PRODUCT / MILESTONE	PM	PF	H	ER	PG	GB	SM	CB	EE	RE	OP-EM	CO	CT	OC	NMFS	FWS	WDFG	TETON	HQ	NPD
J	FEASIBILITY REPORT																				
J J	PLAN FORMULATION		O	☆	☆	☆	☆		☆		☆						☆	☆	☆		
	DEVELOP INITIAL ARRAY OF ALTS		O	☆	☆	☆	☆		☆		☆						☆	☆	☆		
	REDUCE TO INTERM ARRAY OF ALTS		O	☆	☆	☆	☆		☆		☆						☆	☆	☆		
	SELECT FINAL ARRAY OF ALTS		O	☆	☆	☆	☆		☆		☆						☆	☆	☆		
J M	REPORT PREP, REVIEW, & APPROVAL		O														☆	☆	☆		
J I	PUBLIC INVOLVEMENT		O	☆	☆	☆	☆				☆						☆	☆	☆	☆	☆
J A B	HYDROLOGY & HYDRAULIC APPENDIX			O																	
J D	ENVIRONMENTAL COORDINATION				O																
J D C	ENVIRONMENTAL IMPACT STATMENT				O																
J E	FWS COORDINATION ACT REPORT				O												☆				
J D E	ENVIRON RESOURCE INVENTORY RPT				O												☆				
J D F	MITIGATION ANALYSIS RPT				O																
J D G	ENDANGERED SPECIES REPORT				O												☆				
J D H	SECTION 404 (B) (1) ANALYS RPT				O													☆			
J D I	401 STATE WATER QUALITY CERT.				O													☆			
J D J	RECORD OF DECISION (ROD)				O																
J D L	STATEMENT OF FINDINGS (SOF)				O																
J D K	BIOLOGICAL ASSESSMENT				O												☆	☆			
J G	CULTURAL RESOURCE REPORT				O																
J B B	SOCIAL STUDIES / REPORTS				O																
J D	ENVIRONMENTAL APPENDIX				O																
J D N	AQUATIC ECOLOGY				O			☆													
J D O	RIPARIAN AND WETLAND ECOLOGY				O			☆													
J D P	ENDANGERED SPECIES INVESTIGATIONS				O												☆	☆			
J D R	GEOSPATIAL DATA MANAGEMENT				O			☆													
J A	ENGINEERING APPENDIX																				
J A A	SURVEYS & MAPPING							O											☆		
J A C	GEOTECH STUDIES & REPORTS						O														
J A E	ENGINEERING & DESIGN						O		☆												
	BASELINE COST ESTIMATE								O												
J F	HTRW STUDIES & REPORTS									O											
J B	ECONOMIC APPENDIX					O															
J B A	ECONOMIC ANALYSIS REPORT					O															
J B C	INSTITUTION STUDIES / RPTS					O													☆		
J B E	FINANCIAL ANALYSIS RPT					O													☆		
J B F	RISK AND UNCERTAINTY ANALYSIS					O															
J C	REAL ESTATE APPENDIX										O								☆		
K	PROJECT COOPERATION AGREEMEN	O	☆																☆		
L	PROJECT MANAGEMENT PLAN	O	☆										☆	☆					☆		
Z	PROJECT MANAGEMENT	O	☆																☆		

O Primary
☆ Secondary

APPENDIX A

DETAILED TASK ANALYSES

APPENDIX A
DETAILED TASK ANALYSES

The estimate of costs for the Feasibility Study have been developed in the Project Study Plan (PSP) in an appropriate work breakdown structure. The study cost estimates that follow are based on information developed to an appropriate level of detail to minimize the likelihood of substantial change and include associated scopes of study to allow involvement by the Sponsor. These scopes of study serve as the basis for assigning tasks and establishing the dollar value for in-kind contributions. Because of the Sponsor's need to fully evaluate their ability to provide in-kind contributions, an estimate of the cost for each task is provided.

J. STUDY MANAGEMENT.

This task includes all activities related to the day-to-day management of the technical input for the Feasibility Study. Specific activities include: coordinating and monitoring technical work elements and activities for the Government, coordinating technical work elements and activities between the Government and the Sponsor's area of responsibility, suballocating and monitoring funds to technical offices for work elements and activities, conducting technical coordination meetings involving study participants and the Sponsor's counterpart, providing input for various management reports, and preparing correspondence pertaining to the study. Study management costs at the Federal level are based upon an average of 1.5 days a week throughout the study duration, and .50 days a week at the Sponsor's level (assuming 4 years to a Feasibility Review Conference). Reference: Engineer Regulation (ER) 1105-2-100; *Guidance for Conducting Civil Works Planning Studies.*

Program Subaccount Activity	Cost[1]	Responsible Element*
a. Corps of Engineers. Includes all study management activities by the Corps of Engineers.		
(1) Study Manager, 300 days @ $520	$156,000	PL-PF
(2) Travel (4 trips/year to Jackson, Wyoming)	$23,100	PL-PF
(3) Clerical Staff, 20 days @ $260	$5,200	PL-PF
b. Sponsor. Includes all study management activities by the Sponsor.		
(1) Sponsor Project Management, 107.3 days @ $520	$55,790	Sponsor
(2) Travel (1 trip/year to Walla Walla, Washington)	$4,500	Sponsor
(3) Clerical Staff, 10 days @ $260	$2,600	Sponsor
c. Supervision & administration (10 percent)		
(1) Corps	$18,430	PL-PF
(2) Sponsor	$6,289	Sponsor
J STUDY MANAGEMENT:		
CORPS IN-HOUSE SUBTOTAL	$202,730	
SPONSOR SUBTOTAL	$ 69,179	
SUBACCOUNT TOTAL	**$271,909**	

[1]All costs are in December 1996 dollars.

*U.S. Army Corps of Engineers, Walla Walla District
PL-PF - Planning Division, Plan Formulation Branch

JAB. HYDROLOGY STUDIES.

This portion of the study covers the preparation of the hydrology portions of the main report, as well as a hydrology appendix. The hydrology appendix will cover basin hydrology, geomorphology, and hydraulic considerations related to the siting and configuration of habitat restoration measures in the study reach.

	Program Subaccount Activity	Cost[1]	Responsible Element*
a.	Update basin hydrology information. Includes assembling data on gauged and ungauged streams; updating peak flow frequencies, and flow duration.		
	Senior Hydraulic Engineer, 10 days @ $560	$5,600	PL-H
	Engineering Technician, 10 days @ $450	$4,500	PL-H
b.	Define existing conditions (based on year 2000).		
	Senior Hydraulic Engineer, 20 days @ $560	$11,200	PL-H
c.	Estimate future conditions without project. Costs for this portion of the study will cover estimates of future development and its effect on channel hydraulics, along with the residual effects of river adjustment to past construction activities for the next 50 years.		
	Senior Hydraulic Engineer, 20 days @ $560	$11,200	PL-H
d.	Selected alternative measures within the leveed reaches. Studies covered under this item include a literature review; site selections; detailed layout of islands and back channels, and hydraulic modeling; channel surveys; gravel sampling and consultation for island protection schemes.		
	(1) Site visit will include ground reconnaissance of all sites and assistance with collection of detailed physical data.		
	Travel, 2 round trips @ $1,000	$2,000	PL-H
	2 Hydraulic Engineers, 10 days ea. @ $560	$11,200	PL-H
	Per Diem, 20 days @ $90	$1,800	PL-H
	Auto and Fuel, 10 days @ $50	$500	PL-H

Program Subaccount Activity	Cost[1]	Responsible Element*
(2) Grain-size samples at proposed gravel removal sites. Assumes 5-cubic-yard composite samples will be required at each site to complement existing data from other sources.		
Backhoe and Operator, 1 days @ $320	$320	Sponsor
Gravel Sample, 12 samples (3 samples each at 4 sites) @ $1,000	$12,000	Sponsor
(3) Sediment Transport on Snake River. Model sediment transport using Hydrologic Engineering Center (HEC)-6.		
Senior Hydraulic Engineer, 70 days @ $560	$39,200	PL-H
(4) Hydraulic Analysis: HEC-2 modeling of 4 sites.		
Survey at each site (4 sites)	$32,000	Sponsor
Senior Hydraulic Engineer, 36 days @ $560	$20,160	PL-H
Engineering Technician, 8 days @ $450	3,600	PL-H
(5) Develop plans for avulsion control and site monitoring to document the results of gravel removal and other structural modifications.		
Senior Engineer, 35 days @ $560	$19,600	PL-H
e. Final Report Preparation. Costs associated with this item cover the assembly of study results from all Hydrology portions of the study and assemblage into a Hydrology Appendix, as well as the preparation of the Hydrology portions of the main report.		
Senior Engineer, 22 days @ $560	$12,320	PL-H
f. Review Report. Costs associated with this portion of the study are difficult to estimate. They include answering review comments, preparation for review meetings, and possible restudy or rewrite of portions of the study.		
Senior Engineer, 13 days @ $560	$7,280	PL-H

Program Subaccount Activity		Cost[1]	Responsible Element*
g.	Supervision. Costs covered under this item include branch chief attendance at work group and policy meetings and supervision of branch engineers working on study. Assumes 15 percent of total branch hours.		
	Supervisory Hydraulic Engineer, 30 days @ $576	$17,280	PL-H
JAB HYDROLOGY STUDIES:			
CORPS IN-HOUSE SUBTOTAL		$167,500	
SPONSOR SUBTOTAL		$44,320	
SUBACCOUNT TOTAL		**$211,820**	

[1]All costs are in December 1996 dollars.

*U.S. Army Corps of Engineers, Walla Walla District
PL-H - Planning Division, Hydrology Branch

JAB. GROUNDWATER:

Program Subaccount Activity	Cost[1]	Responsible Element*
a. This study will take place on the west side of the Snake River below the junction of the Gros Ventre and Snake River and north of Fish Creek.		
(1) Surface Water monitoring plan		Sponsor
(2) Groundwater monitoring Plan		Sponsor
(3) Water Quality monitoring		Sponsor
(4) Analysis and report writing		Sponsor
JAB GROUNDWATER:		
CORPS IN-HOUSE SUBTOTAL	-0-	
SPONSOR SUBTOTAL	$90,800	
SUBACCOUNT TOTAL	**$90,800**	

[1]All costs are in December 1996 dollars.

JAE. ENGINEERING AND DESIGN.

This account includes the design of the various alternatives. Field investigations, including exploratory test pits, will determine foundation conditions. Designs will be at a feasibility-study level, which includes only minimal details. It is assumed that a riprap source will be available, and it will be determined by a different study outside the scope of this work. Budget level cost estimates will be provided for the alternatives. A microcomputer-aided cost estimating system (MCACES) estimate will be made for the selected alternative. The Corps requires an estimate of this level.

It is assumed that a riprap source will be available. This source will be determined by a separate study.

Program Subaccount Activity		Cost[1]	Responsible Element*
a.	Site reconnaissance to familiarize the designer with the field conditions.		
	(1) Civil Engineer, 10 days @ $541	$5,410	EN-GB
	(2) Travel, per diem, car rental	$2,000	Corps
b.	Explorations using test pits dug with a backhoe. These explorations are for the tasks that follow:		
	(1) Civil Engineer Technician, 10 days @ $352	$3,520	EN-GB
	(2) Backhoe, 10 days @ $400	$4,000	Sponsor
	(3) Travel, per diem, car rental	$2,000	Corps
c.	Provide feasibility level design for the restoration of channels that have been designated by U.S. Army Corps of Engineers, Walla Walla District (CENPW), Hydrology Branch. CENPW, Design Branch, will include a rough layout and quantities for an estimate. The following estimate assumes four sites:		
	(1) Supervising Engineer, 2 days @ $708	$1,416	EN-GB
	(2) Civil Engineer, 12 days @ $541	$6,492	EN-GB
	(3) Civil Engineering Tech, 6 days @ $352	$2,112	EN-GB
	(4) Cost Engineer, 8 days @ $541	$4,328	EN-CB
	(5) CADD 6 days @ $240	$1,440	Corps

Program Subaccount Activity	Cost[1]	Responsible Element*
d. Island restoration and protection. Provide feasibility level design for island protection and island restoration. The islands and location of the protection will be determined by CENPW, Hydrology Branch. The CENPW, Design Branch, will include a rough layout and quantities. This scope anticipates four islands.		
(1) Supervising Engineer, 2 day @ $708	$1,416	EN-GB
(2) Civil Engineer, 15 days @ $541	$8,115	EN-GB
(3) Engineering Tech, 6 days @ $352	$2,112	EN-GB
(4) Cost Engineer, 8 days @ $541	$4,328	EN-CB
(6) CADD, 6 days @ $240	$1,440	Corps
e. Levee toe and spur dikes. Provide feasibility level design for spur dikes. The location will be determined by CENPW, Hydrology Branch. Topography may not be available if the chosen areas are under water during mapping (Task II). A rough layout and quantities will be provided. Four locations are anticipated for this scope.		
(1) Supervising Engineer, 2 days @ $708	$1,416	EN-GB
(2) Civil Engineer, 12 days @ $541	$6,492	EN-GB
(3) Civil Engineering Tech, 6 days @ $352	$2,112	EN-GB
(4) Cost Engineer, 8 days @ $541	$4,328	EN-CB
(5) CADD, 6 days @ $240	$1,440	Corps
f. MCACES Estimate. Provide MCACES estimate for the selected alternative. HQUSACE will not accept a report without this estimate.		
(1) Civil Engineer, 3 days @ $541	$1,623	EN-GB
(2) Cost Engineer, 7 days @ $541	$3,787	EN-CB

Program Subaccount Activity	Cost[1]	Responsible Element*
g. Survey of sites. Provide topography of four sites with on ground survey crew accomplished in two trips.	$107,180	EN-DB-SM
JAE ENGINEERING AND DESIGN:		
CORPS IN-HOUSE SUBTOTAL	$174,507	
SPONSOR SUBTOTAL	$4,000	
SUBACCOUNT TOTAL	**$178,507**	

[1]All costs are in December 1996 dollars.

*U.S. Army Corps of Engineers, Walla Walla District

EN-GB - Engineering Division, Geology and Dam Safety Section

EN-CB - Engineering Division, Cost Engineering Branch

EN-DB-SM - Engineering Division, Design Branch, Survey and Mapping Section

JBA. ECONOMIC AND INSTITUTIONAL STUDIES.

This task will be performed by CENPW and the Sponsor. It will include a sensitivity analysis, an environmental restoration incremental analysis study, and an analysis of the Sponsor's financial plan and ability to pay.

The incremental analysis will determine the most cost effective measures to implement environmental improvement in the study area.

A sensitivity analysis will quantify uncertainties in key variables such as variations in the government estimate of construction costs, habitat units that will be produced by specific project elements, and others identified through the study process that affect the cost and benefits of each measure.

An economic appendix will be provided for inclusion in the technical documentation for the Feasibility Study that will include the development of incremental costs and benefits for each alternative.

The financial capability analysis will examine the Sponsor's organizational, legal, and financial capability to undertake the required financial obligations for implementation of the project after it is authorized for construction by Congress.

The Sponsor will prepare a financing plan and an accompanying statement of financial capacity (including a statement of revenues and a statement of funds for the last 3 years).

	Program Subaccount Activity	Cost[1]	Responsible Element*
a.	Assessment of existing data related to floodplain and natural habitat		
	Economist, 5 days @ $519	$2,595	PL-PF
b.	Develop incremental analysis for all cost-effective alternatives.		
	Economist, 15 days @ $519	$7,785	PL-PF
c.	Calculate incremental benefits of one or more alternatives.		
	Economist, 5 days @ $519	$2,595	PL-PF
d.	Conduct sensitivity analysis.		
	Economist, 5 days @ $519	$2,595	PL-PF
e.	Financial capability statement on the sponsor's ability to participate.		
	Economist, 5 days @ $519	2,595	PL-PF
	Sponsor	$10,000	Sponsor
f.	Prepare economic appendix.		
	Economist, 15 days @ $519	$7,785	PL-PF
g.	Travel and per diem costs.		
	(1 trip/1 person/air/car rental-1996)	$3,000	PL-PF
	(1 trip/1 person/air/car rental-1997)		
h.	Supervision and administration	$5,200	PL-PF
JBA ECONOMIC AND INSTITUTIONAL STUDIES:			
CORPS IN-HOUSE SUBTOTAL		$34,150	
SPONSOR SUBTOTAL		$10,000	
SUBACCOUNT TOTAL		**$44,150**	

[1]All costs are in December 1996 dollars.

*U.S. Army Corps of Engineers, Walla Walla District
PL-PF - Planning Division, Plan Formulation Branch

JC. REAL ESTATE APPENDIX, MAJOR STUDY PRODUCTS:

Real Estate Division study input will include preparation of preliminary real estate cost estimates for project right-of-way requirements, participation in pre-project cooperation agreement activities, preparation of a real estate supplement for inclusion in the Feasibility Report, preparation of a gross appraisal report, and preparation of a baseline cost estimate for real estate prepared in the Code of Accounts format.

Program Subaccount Activity	Cost[1]	Responsible Element*
a. Coordination. This activity includes, but is not limited to, CENPW, Real Estate Division (RE) participation in team meetings, negotiation of work agreements, securing required rights of entry for testing/investigative purposes, coordination with other offices on project data needed for Real Estate's major study products, and monitoring of progress and findings associated with Real Estate study products. This project will require additional coordination efforts with the local Sponsor, attendance at public meetings, *etc.*		
(1) Realty Officer - 4 days @ $650	$2,600	Sponsor
(2) Appraiser - 3 days @ $600	1,800	Sponsor
(3) Secretary - 0.4 day @ $250	100	Sponsor
(4) Meetings, working with sponsor on reporting requirements; reviewing qualifications of sponsor's appraiser (approval/disapproval of same remains with the Corps); supplying required estate language (standard and non-standard).		
Realty Officer - 3 days @ $650	$2000	Corps

Program Subaccount Activity	Cost[1]	Responsible Element*
b. Preparation of Preliminary Real Estate Cost Estimates. This activity includes the development of preliminary (Reconnaissance level of detail) estimate(s) of total real estate costs associated with proposed project scenarios. The Real Estate Cost Estimate(s) include a value estimate of the Project's real property requirement, an estimate of any Public Law 91-646 relocation payments required as a result of the Project's real property acquisitions, an estimate of the local Sponsor's administrative cost to accomplish the project's real property requirements and an estimate of the CENPW administration cost to assist and monitor the local Sponsor's real property acquisition program.		
(1) Realty Officer - 0.3 day @ $650	$ 200	Sponsor
(2) Appraiser - 2 days @ $600	1,200	Sponsor
(3) Realty Specialist - 1 day @ $500	500	Sponsor
(4) Secretary - 0.4 day @ $250	100	Sponsor
(5) Providing Sponsor with reporting criteria and interpret/lend assistance as required; review and approve all valuation products.		
Realty Officer - 4 -5 days @ $650	$2,900	Corps

Program Subaccount Activity	Cost[1]	Responsible Element*
c. Preparation of Gross Appraisal. This activity includes preparation of a Gross Appraisal Report, which provides a detailed estimate of all real estate costs associated with acquisition of the project's real property requirements. (See ER 405-1-12, *Real Estate* Handbook, Draft Chapter 12, Section III, Appraisals, paragraph 12-12b; and Real Estate Policy Guidance Letter Number 3, *Guidance for Preparation of Gross Appraisals*, dated May 31, 1991.)		
(1) Appraiser - 2.5 days @ $600	$ 1,500	Sponsor
(2) Sponsor - 4 sites @ $2,500 each	10,000*	Sponsor
(3) Sponsor - 1 day @ $650	650	Sponsor
(4) Provide sponsor with reporting criteria and interpret/lend assistance as required; review for adequacy.		
Realty Officer - 2.3 days @ $650	$1,500	Corps

*In accordance with the above-mentioned Real Estate Policy Guidance Letter No. 3, with CENPW supervision, review, and approval.

Program Subaccount Activity		Cost[1]	Responsible Element*
d.	Preparation of Real Estate Supplement. This activity includes preparation of the Real Estate Supplement (RES), which is an overall plan describing the minimum real estate requirements for the Project (see ER 405-1-12, Draft Chapter 12).		
	(1) Realty Officer - 0.3 day @ $650	$ 200	Sponsor
	(2) Appraiser - 5 days @ $600	3,000	Sponsor
	(3) Realty Specialist - 2 days @ $500	1,000	Sponsor
	(4) Cartographer - 2 days @ $400	800	Sponsor
	(5) Secretary - 0.4 days @ $250	100	Sponsor
e.	Review and Revise Report Documents. This activity includes all CENPW-RE actions involved in reviewing the Feasibility Report and responding to U.S. Army Corps of Engineers, North Pacific Division(CENPD) comments.		
	(1) Realty Officer - 0.3 day @ $650	$ 200	Sponsor
	(2) Appraiser - 2 days @ $600	1,200	Sponsor
	(3) Realty Specialist - 1 day @ $500	500	Sponsor
	(4) Secretary - 0.4 day @ $250	100	Sponsor

Program Subaccount Activity	Cost[1]	Responsible Element*
f. Preparation of Baseline Cost Estimate for Real Estate. This activity includes accounting for the Project's total estimated real estate cost in Code of Accounts format as required by Engineer Circular (EC) 1110-2-538 under feature codes 01, Lands and Damages, and 02, Relocations, as necessary. This estimate of total real estate cost should include estimated costs for all Federal and Local Sponsor activities necessary for completion of the project.		
(1) Realty Officer - 0.3 day @ $650	$ 200	Sponsor
(2) Appraiser -1.2 days @ $600	700	Sponsor
(3) Realty Specialist - 1 day @ $500	500	Sponsor
(4) Secretary - 0.4 day @ $250	100	Sponsor
(5) Provide format and explain; review and assure sufficiency of detail.		
Realty Officer - 1 day @ $600	$600	Corps
g. Travel. Coordination and review of study products; attending meetings.		
Estimated cost	$2,600	Corps
JC REAL ESTATE APPENDIX, MAJOR STUDY PRODUCTS:		
CORPS IN-HOUSE SUBTOTAL	$9,600	
SPONSOR SUBTOTAL	$27,250	
SUBACCOUNT TOTAL	**$36,850**	

[1]All costs are in December 1996 dollars.

JD. ENVIRONMENTAL APPENDIX.

JDC. NATIONAL ENVIRONMENTAL POLICY ACT COMPLIANCE.

a. Prepare Environmental Impact Statement (EIS).

(1) Public Involvement. Includes publication of the Notice of Intent in the Federal Register, EIS Public Scoping Meeting in Jackson Hole, draft EIS Public Hearing/Workshop in Jackson Hole, and publication of three Fact Sheets. The fact sheets will be published just prior to the scoping meeting, prior to the draft EIS release, and prior to the final EIS release. Fact sheets will be distributed to everyone on the mailing list plus some for local distribution through various outlets.

(2) Draft EIS For Public Review. Utilize information gathered from scoping meetings, hydrological, biological, and engineering studies to develop a preliminary draft for internal review and a draft for agency and public review. The EIS will develop the existing environment, a description of the alternatives, analysis of impacts to be caused by the alternatives, identification of the preferred alternative, discussion of necessary mitigation, and status of compliance with all Federal Laws which apply to the Project. Distribution will be made to those on the mailing list. Staff will also review and provide comments.

(3) Preliminary Final EIS for U.S. Army Corps of Engineers, Headquarters (HQUSACE) Review. Incorporate all comments provided by the agencies and the public into the EIS process, address each comment as appropriate, incorporate valid and significant issues into the project effort, and prepare a preliminary final EIS to be reviewed internally and to be sent to HQUSACE for review prior to finalization. Distribution will be within the Corps, any Co-Lead Agencies and Cooperating Agencies, and to the Sponsor(s).

(4) Final EIS for Review. Incorporate HQUSACE comments, reformulate the Project as necessary, and issue a final EIS for review by the agencies and the public. Distribution will be made to those on the mailing list.

(5) Draft Record of Decision (ROD). Publish a draft ROD for agency and public review. The ROD will summarize the action to be taken, along with all mitigating requirements. The ROD will address issues still not resolved and identify how these issues will be handled. Distribution will be made to those on the mailing list.

(6) Signed ROD. The ROD will be signed by the CENPW Commander which will allow designs and specifications work to begin as soon as money is appropriated.

b. Clean Water Act Requirements. Outline requirements for compliance with the Clean Water Act (CWA) for in-water work and water quality. This will entail compliance with §404 and §401, which includes development of the §404 (b) (1) evaluation for the project from a composite point of view, and coordination of §401 certification from the State of Wyoming. Also included is the discovery and coordination of any other permits required for in-water work in

Wyoming. A list of requirements for each alternative and an evaluation of impacts expected from implementation of each alternative.

c. Endangered Species Act Requirements. Determine those flora and fauna species which have been classified as endangered, threatened, or candidates for listing under the guidelines of the Endangered Species Act (ESA) of 1973 as amended. Comply with ESA to the extent necessary in terms of assessments and consultation, either informal or formal. Prepare and submit a request for a species list from the United States Fish and Wildlife Service (USFWS) Office in Cheyenne, Wyoming. Prepare a biological assessment for those species identified by the USFWS. Address the presence of the species in the region and in the project area. Address the life requisites of the identified species and to what degree the project area provides those life requisites. Determine how the project would impact those life requisites if the preferred alternative were to be built. Make a determination on the degree of impact to be caused for each species identified and request concurrence from the USFWS. If a significant impact is determined, then request for immediate formal consultation. If formal consultation is required, a series of meetings between the Corps, the Sponsor, and the USFWS will occur. The consultation will be completed within a 90-day period, once requested, and assuming all parties can agree to a solution. The USFWS will produce a Biological Opinion with or without a Jeopardy Determination. Reasonable and prudent measures will be identified for implementation as agreed upon by the involved agencies and groups. Failure to come to agreement will delay the project. Failure to adopt and implement the reasonable and prudent measures will be cause to reopen Formal Consultation and again delay the project. Formal coordination is not a given. We presently have adequate knowledge of endangered and threatened species concerns in the Jackson Hole area to be able to avoid formal consultation. However, if formal consultation becomes necessary, then additional funds will be needed to participate in the process as defined by the ESA.

d. Fish and Wildlife Coordination Act Requirements. Develop Scope of Work to involve USFWS in providing resource information, assessing impacts, producing future with and without project, participate as a member of the Tri-agency team in Habitat Evaluation Procedure modifications and application, and participate in identifying additional measures and possible alternatives in development of the restoration project. The product is a draft Coordination Act Report and a final Coordination Act Report.

e. Cultural Resource Requirements. Conduct cultural resource assessments in accordance with the National Historic Preservation Act of 1966 (NHPA) §106, the Archaeological and Historical Preservation Act of 1974 (AHPA). Close Coordination will be kept with the State Historical Preservation Office (SHPO).

(1) Records Search. Coordinate with the Wyoming SHPO for a search of archaeological records held by that office, as well as published archaeological reports concerning the project area.

(2) Cultural Resources Survey. Conduct field surveys of the project areas to determine the presence and condition of cultural sites.

(3) National Register of Historic Places Eligibility Determination. Coordinate with the Wyoming SHPO and other appropriate groups to determine the eligibility of cultural resources for inclusion on the National Register of Historic Places (NRHP). Site testing may be required to determine NRHP eligibility.

(4) Mitigation. Develop appropriate mitigation responses for NRHP-eligible sites to be impacted by project activities. This task will be carried out in consultation with the Wyoming SHPO, the Advisory Council on Historic Preservation (ACHP) and other appropriate groups. A Programmatic Agreement outlining cultural resource management actions will be developed as part of the consultation process.

	Program Subaccount Activity	Cost[1]	Responsible Element*
a.	Prepare environmental impact statement (two meetings and preparation).		
a.1	Public involvement.		
	Environmental Resource Specialist, 10 days @ $300	$3,000	PL-ER
	Fishery Biologist, 5 days @ $490	$2,450	PL-ER
	Travel/Per Diem, 1 @ $4,000	$4,000	PL-ER
a.2	Draft EIS for public review.		
	Environmental Resource Specialist, 30 days @ $300	$9,000	PL-ER
	Wildlife Biologist, 5 days @ $460	$2,300	PL-ER
	Fishery Biologist, 5 days @ $490	$2,450	PL-ER
	Hydrologist, 5 days @ $560	$2,800	PL-HY
	Limnologist, 5 days @ $385	$1,925	PL-ER
	Archaeologist, 5 days @ $360	$1,800	PL-ER
	Landscape Architect, 5 days @ $492	$2,460	PL-ER
	Printing, 1 @ $5,000	$5,000	PL-ER
a.3	Final EIS for review.		
	Environmental Resource Specialist, 30 days @ $300	$9,000	PL-ER
	Wildlife Biologist, 5 days @ $460	$2,300	PL-ER
	Fishery Biologist, 5 days @ $490	$2,450	PL-ER
	Hydrologist, 5 days @ $560	$2,800	PL-HY
	Limnologist, 5 days @ $385	$1,925	PL-ER
	Archaeologist, 5 days @ $360	$1,800	PL-ER
	Landscape Architect, 5 days @ $492	$2,460	PL-ER
	Printing, 1 @ $5,000	$5,000	PL-ER
a.4	Draft ROD.		
	Environmental Resource Specialist, 2 days @ $300	$600	PL-ER
a.5	Signed ROD.		
	Environmental Resource Specialist, 1 day @ $300	$300	PL-ER
b.	Clean Water Act requirements.		
	Limnologist, 5 days @ $385	$1,925	PL-ER
	Travel/Per Diem, 1 @ $1,300	$1,300	PL-ER

	Program Subaccount Activity	Cost[1]	Responsible Element*
c.	Endangered Species Act requirements.		
c.1	Endangered and Threatened Species List.		
	Wildlife Biologist, 1 day @ $460	$460	PL-ER
c.2	Biological assessment.		
	Wildlife Biologist, 2 days @ $460	$920	PL-ER
d.	Fish and Wildlife Coordination Act requirements.		
	Wildlife Biologist, 5 days @ $460	$2,300	PL-ER
	Fishery Biologist, 3 days @ $490	$1,470	PL-ER
	USFWS, 1 @ $10,000	$10,000	PL-ER
e.	Cultural resource requirements.		
e.1	Records search.		
	Archaeologist, 3 days @ $360	$1,080	PL-ER
e.2	Conduct cultural surface survey.		
	Archaeologist, 5 days @ $360	$1,800	PL-ER
e.3	National Register of Historic Places eligibility determination.		
	Archaeologist, 5 days @ $360	$1,800	PL-ER
f.	Graphical Support.	$2,000	DPS
g.	Branch supervision and administration.		
	Branch Chief, 12 days @ $640	$7,680	PL-ER
	Secretary, 5 days @ $200	$1,000	PL-ER
JDC NATIONAL ENVIRONMENTAL POLICY ACT COMPLIANCE:			
CORPS IN-HOUSE SUBTOTAL		$99,555	
SPONSOR SUBTOTAL		-0-	
SUBTOTAL		$99,555	

[1]All costs are in December 1996 dollars.

*U.S. Army Corps of Engineers

PL-ER - Planning Division, Environmental Resources Branch

PL-HY - Planning Division, Hydrology Branch

DPS - Defense Printing Service

JDE. AQUATIC ECOLOGY INVESTIGATIONS

a. Assemble Existing Fish Population and Habitat Data. Assemble all existing fish population and habitat survey data available for the project area. Potential sources include:

- Wyoming Game and Fish Department (WGFD), District Office in Jackson, WY
- Wyoming Game and Fish Department, State Office, In-stream Flow Section, Cheyenne, WY
- U.S. Fish and Wildlife Service (USFWS), Cheyenne, WY
- U.S. Geological Survey, Cheyenne, WY
- National Biological Service, Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie, WY
- Trout Unlimited, Wyoming Council, Jackson, WY

Annotated bibliography on fish population and habitat in Jackson Hole area with an emphasis on Snake River Cutthroat Trout (SRCT).

b. Survey of Main Channel Access to Side Channels Important for Spawning. Conduct a feasibility-level survey of the 500-year floodplain and identify areas within the main channel associated with Spring and Fish Creek side channels with potential for development as SRCT spawning/nursery habitat. Utilize local expertise, previous work done in the project area, existing aerial photography, current water rights, and site visits as appropriate. A map will be produced which identifies areas having potential for development and a report describing the criteria used in making the selections.

(1) Quantify River Habitats. Identify specific reaches in the main channel specifically associated and unassociated with Spring and Fish Creek side channels that exhibit high potential for development as SRCT spawning and nursery habitat. This will require acquisition of detailed bathymetric and topographic data including side channel/spring creek thalweg profiles and channel structure and morphometry.

(2) Review Sediment Load Rates and Quantities in Main Channel. Based upon CENPW, Hydrology Branch, sediment transport analyses, evaluate the expected suspended sediment loads delivered down the main channel between the levees from the Snake River to quantify restrictions to decreased velocity and other spawning habitat parameters. This will entail retrieving data from nearby Snake River water quality monitoring stations for sediment transport studies accomplished near the project reach. Collection of additional suspended sediment concentration data may be required during the period of highest fine sediment discharge.

c. Detailed Survey of Mainstem Snake River. Identify areas within the mainstem of the Snake River channel with high potential for in-stream structural habitat improvements, with emphasis on over-wintering habitat for adult SRCT. This will require acquisition of detailed data on existing mainstem channel morphometry as well as detailed data on the characteristics of high quality SRCT over-wintering habitat in the Snake River that can be duplicated in the project area.

Products will include a small scale map showing reaches with high potential for development and small scale maps showing WGFD stream survey data.

d. Develop Restoration Plan.

(1) Habitat Development and Operation and Maintenance Plan. Prepare habitat restoration alternatives that emphasize main channel access for SRCT spawning and nursery habitat into Spring and Fish Creeks and adult SRCT over-wintering habitat in the Snake River main channel. This will require utilization of topographic, hydrologic, and demographic data, as well as extensive input by WGFD. This plan should include a long-term (10-year) operation and maintenance section identifying the potential for habitat restoration within all 12 proposed sites. Prepare a long-term operation and maintenance plan for structural and non-structural habitat improvements in the Snake River main channel with accessibility to important Spring Creek side channel areas identified in the 10-year Habitat Development Plan. An important consideration in maintaining the quality of spawning and nursery habitats is sedimentation and its effect on inter-gravel flow.

e. Biological Monitoring of Spur Dike. Through cooperation with WGFD collect biological data of SRCT and other native fish response to spur dike location and construction. Response variables would include utilization and changes in production based on fish numbers and relative size/weight in response to physical variables of velocity and microhabitat changes. If spur dike construction and placement are beneficial, the biological monitoring would be useful in designing similar restoration measures on a larger geographical scale.

	Program Subaccount Activity	Cost[1]	Responsible Element*
a.	Assemble existing fish population and habitat data. Fishery Biologist, 6 days @ $490	$2,940	PL-ER
b.	Survey of main channel access to side channels important for spawning. Fishery Biologist, 4 days @ $490	$1,960	PL-ER
b.1	Quantify river habitats. Fishery Biologist, 6 days @ $490	$2,940	PL-ER
b.2	Review sediment load rates and quantities in main channel. Fishery Biologist, 4 days @ $490	$1,960	PL-ER
c.	Detailed survey of main channel snake river. Fishery Biologist, 6 days @ $490	$2,940	PL-ER
d.	Develop restoration plan.		
d.1	Habitat development, operation, and maintenance. Fishery Biologist, 8 days @ $490 Hydraulic Engineer, 3 days @ $540	$3,920 $1,620	PL-ER PL-ER
e.	Biological monitoring of spur dike. Fishery Biologist, 10 days @ $490 Wyoming Game & Fish, 1 lump sum cost @ $11,500	$4,900 $11,500	Sponsor Sponsor
f.	Branch supervision and administration. Branch Chief, 2 days @ $640 Secretary, 2 days @ $200	$1,280 $400	PL-ER PL-ER
JDE AQUATIC ECOLOGY INVESTIGATIONS:			
CORPS IN-HOUSE SUBTOTAL		$19,960	
SPONSOR SUBTOTAL		16,400	
SUBTOTAL		$36,360	

[1]All costs are in December 1996 dollars.

*U.S. Army Corps of Engineers, Walla Walla District,
PL-ER - Planning Division, Environmental Resources Branch.

JDE. CHANNEL HABITAT ASSESSMENT.

a. Cover Type. Update existing cover type information within the channel approximately two (2) river mile segments above the selected island and approximately five (5) river mile segments below the selected island. All overstory cover typing will be done using current aerial photography of the channel and comparing to existing mapping. Ground reconnaissance, as required, will be completed to verify overstory typing and determine understory composition.

All cover typed information will be transferred into a digital format based on National Standards established for Geographic Information System (GIS) information. Database linkages will be created to allow for analysis of habitat changes proposed by project alternatives.

b. Habitat Evaluation Procedures. Conduct a Habitat Evaluation Procedure (HEP) on in-stream channel habitat to be affected by the proposed alternatives. Models for wildlife species, which characterize the cover type habitat will be selected and ground surveys will be conducted to gather information required to run the selected species models. Habitat units will be determined.

c. Products. Cover type mapping of stream channel and HEP model results in form of habitat units.

Program Subaccount Activity	Cost	Responsible Element*
Channel habitat assessment.		
Wildlife Biologist, 30 days @ $465	$13,950	PL-ER
GIS Technician, 20 days @ $270	$5,400	PL-ER
Computer Specialist, 5 days @ $400	$2,000	PL-ER
Travel/Per Diem, 1 @ $3,000	$3,000	PL-ER
Branch supervision and administration.		
Branch Chief, 3 days @ $640	$1,920	PL-ER
Secretary, 2 days @ $200	$400	PL-ER
JDE CHANNEL HABITAT ASSESSMENT:		
CORPS IN-HOUSE SUBTOTAL	$26,670	
SPONSOR SUBTOTAL	-0-	
SUBTOTAL	$26,670	

*U.S. Army Corps of Engineers, Walla Walla District,
PL-ER - Planning Division, Environmental Resources Branch.

JDE. EVALUATION OF ALTERNATIVES.

a. Analyze Alternatives Using Habitat Evaluation Procedure. All alternatives formulated and identified as viable will be analyzed using the HEP. A matrix of benefits will be developed with a discussion on the results. Benefits will be in terms of habitat units.

b. Analyze Future without Project Condition. Assess future conditions of stream vegetative habitat for 10-, 25-, and 50-year time periods, considering no change to the habitat from the present condition. Output in habitat units.

c. Analyze Future with Project Condition. Assess future condition of stream vegetative habitat for 10-, 25-, and 50-year time periods, considering proposed alternatives to existing habitat. Output in habitat units.

d. Develop Incremental Improvements to Alternatives. Incremental improvements within alternatives, primarily the preferred alternative, will be considered to fine tune costs and to maximize benefits.

e. Analyze Habitat Restoration Alternatives Through Fish Production. Determine the relationship between the quality and quantity of spawning/nursery habitat and over-wintering habitat, and the production/abundance of SRCT. Determine the amount of biomass, or number of individual SRCT's, that would be produced by each fish habitat restoration alternative.

	Program Subaccount Activity	Cost[1]	Responsible Element*
a.	Analyze alternatives.		
	Wildlife Biologist, 10 days @ $465	$4,650	PL-ER
	GIS Technician, 10 days @ $270	$2,700	PL-ER
	Fishery Biologist, 5 days @ $490	$2,450	PL-ER
	Branch supervision and administration		
	Branch Chief, 2 days @ $640	$1,280	PL-ER
	Secretary, 2 days @$200	$400	PL-ER
JDE EVALUATION OF ALTERNATIVES:			
CORPS IN-HOUSE SUBTOTAL		$11,480	
SPONSOR SUBTOTAL		-0-	
SUBTOTAL		$11,480	

[1] All costs are in December 1996 dollars.

*U.S. Army Corps of Engineers, Walla Walla District,
PL-ER - Planning Division, Environmental Resources Branch

JDN. GEOSPATIAL DATA MANAGEMENT.

a. Existing Data Verification. Review the following data sets (files) for accuracy and coordinate changes and documentation with the proper source or authority. Verify and correct data and connection to tables in the CENPW GIS database.

FILE	**THEME**
jhltrans.dgn	Transportation
jhlbound.dgn	Boundaries
jhlhydro.dgn	Hydrology
jhlsurvey.dgn	Survey
jhlowner.dgn	Land Ownership
56levee.dgn	Levees 1956
86levee.dgn	Levee 1986

b. Conversion of Data to National Data Standards. Convert the database, features, names, coding and tables to the Tri-Service geospatial data standards.

c. Creation of Metadata. Executive Order 12906, Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure, dated April 11, 1994, requires that metadata information be created on existing geospatial information and be provided to the National Clearing House. Metadata information sent to the National Clearing House that will comply with the Standards for Digital Geospatial Metadata, dated June 8, 1994.

d. New Geospatial Data and Applications. Coordinate new geospatial data to ensure that District and National standards are met. Includes ensuring that the National Clearinghouse is checked for existing data. Coordinate data with other Federal and State Agencies. Coordinate and ensure that new geospatial data from CENPW Survey and Mapping, Real Estate, Plan Formulation, Hydrology, Environmental Resources, and Geotechnical Branch is entered in the CENPW GIS. Ensure that all new spatial data has metadata created and entered in the National Clearinghouse. Includes all types of spatial data, both automated [GIS and Computer-Aided Drafting and Design (CADD)] and data recorded manually on paper. Also includes photography created for this project.

	Program Subaccount Activity	Cost[1]	Responsible Element*
a.	Existing data verification.		
	Landscape Architect, 5 days @ $492	$2,460	PL-ER
	GIS Technician, 10 days @ $270	$2,700	PL-ER
	Cartographic Technician, 10 days @ $400	$4,000	EN-SM
c.	Creation of metadata.		
	Landscape Architect, 1 day @ $492	$492	PL-ER
	Cartographic Technician, 2 days @ $400	$800	PL-ER
	GIS Technician, 3 days @ $270	$810	EN-SM
d.	New spatial data and applications.		
	Landscape Architect, 14 days @ $492	$6,888	PL-ER
e.	GIS system cost.		
	System Cost, 1 @ $300	$300	IM-R
f.	Branch supervision and administration.		
	Branch Chief, 1 day @$640	$640	PL-ER
	Secretary, 1 day @ $200	$200	PL-ER
JDN GEOSPATIAL DATA MANAGEMENT:			
CORPS IN-HOUSE SUBTOTAL		$19,290	
SPONSOR SUBTOTAL		-0-	
SUBTOTAL		$19,290	

[1]All costs are in December 1996 dollars.

*U.S. Army Corps of Engineers, Walla Walla District

PL-ER - Planning Division, Environmental Resources Branch

EN-SM - Engineering Division, Survey & Mapping Section

IM-R - Information Management Office, Plan Design & Implementation Branch

	Program Subaccount Activity	Cost[1]	Responsible Element*
JDC	National Environmental Policy Act Compliance	$99,555	Corps
JDE	Aquatic Ecology Investigations	$19,960	Corps
		$16,400	Sponsor
JDE	Channel Habitat Assessment	$26,670	Corps
JDE	Evaluation of Alternatives	$11,480	Corps
JDN	Geospatial Data Management	$19,290	Corps
JD	**ENVIRONMENTAL APPENDIX**		
CORPS IN-HOUSE SUBTOTAL		$176,955	
SPONSOR SUBTOTAL		$16,400	
SUBACCOUNT TOTAL		**$193,355**	

JI. PUBLIC INVOLVEMENT.

This task will be performed by CENPW and the Sponsor. This task primarily consists of coordinating the study and results with the public; conducting public meetings and workshops; and responding to inquiries. The public meetings include a scoping workshop at the beginning of the study and a final meeting after the draft Feasibility Report and EIS are distributed for public review. Also included is preparation of a public involvement plan to guide public involvement activities throughout the study. Four Steering Committee meetings are planned each year.

The Sponsor will prepare a proactive public involvement plan, be responsible for hosting public meetings, and provide documentation. This task includes arranging for accommodations, inviting the public, maintaining a mailing list of property owners and local interested parties, and printing and distributing announcements. The Sponsor will maintain close contact with the media and promote awareness events.

Program Subaccount Activity	Cost[1]	Responsible Element
a. Maintain mailing list(s).		
Technical staff, 5 days @ $300	$1,500	Sponsor
b. Steering committee meetings (four per year, for a total of twelve).		
Room @ no charge	$0	
Recorder, 2 hours per meeting times 12 meetings, equals 3 days @ $300	$900	Sponsor
c. Public meetings (two).		
(1) Printing and distributing announcements	$2,500	Sponsor
(2) Public scoping meeting		
Room @ $400	$400	Sponsor
Recorder, 3 days @ $300	$900	Sponsor
(3) Draft EIS		
Room @ $400	$400	Sponsor
Recorder, 3 days @ $300	$900	Sponsor
(4) Media announcements, *etc.*	$1,000	Sponsor
(5) Proactive public coordination plan.	$5,000	Sponsor
d. Develop project cost recovery plan.	$5,000	Sponsor
JI PUBLIC INVOLVEMENT		
CORPS IN-HOUSE SUBTOTAL	$0	
SPONSOR SUBTOTAL	$18,500	
SUBACCOUNT TOTAL	**$18,500**	

[1]All costs are in December 1996 dollars.

JJ. PLAN FORMULATION AND EVALUATION.

This account provides for the process for describing and evaluating alternatives that lead to the identification of the recommended plan. Habitat Suitability Index(s) and costs will be developed for restoration features. An interdisciplinary team and the Sponsor will identify alternatives and conduct analysis following the guidance provided in Water Resources Support Center (WRSC) *Cost Effectiveness Analysis for Environmental Planning*, dated October 1994. Initial alternative analysis will utilize the scope of work present in this document. Alternative evaluation will use an iterative process to screen candidate plans and identify alternatives to be studied in more detail. The plan formulation process, which will result in identification of the plan that maximizes net benefits, includes the "without project" and "with project" conditions. Net benefits for the alternatives will be determined by the difference between the "without" and "with-project" conditions. The recommended plan will be that alternative that maximizes net benefits, unless the Sponsor requests a different alternative and is willing to assume the incremental cost. For the purpose of estimating the cost of this Feasibility Study, costs were included for the detailed analysis of four sites with multiple measures. References: ER 1005-2-100, *Guidance for Conducting civil Works Planning Studies* and ER 200-2-2, *Procedures for Implementing NEPA*.

Program Subaccount Activity			Cost[1]	Responsible Element*
a. Identify and specify initial restoration alternatives. This activity includes the identification and description of all viable alternatives for achieving the study objective to provide ecosystem restoration to the study area. This scoping will address structural and non-structural alternatives, including the initial array of restoration measures presented in this report.				
(1)	PL-PF	5 days @ $520	$2,600	PL-PF
(2)	PL-PH	2 days @ $520	$1,040	PL-H
(3)	PL-ER	2 days @ $520	$1,040	PL-ER
(4)	EN-GB	2 days @ $570	$1,140	EN-GB
(5)	Sponsor	2 days @ $520	$1,040	Sponsor

Program Subaccount Activity			Cost[1]	Responsible Element*
b. Compare initial alternatives. The identified alternatives will be screened with consideration to completeness, effectiveness, efficiency, and acceptability. This activity will be documented by establishment of screening criteria and a comparison of the resulting impacts. Alternatives that pass this screening will be compared to the "without project" condition to determine which alternative will maximize the environmental outputs.				
(1)	PL-PF	2 days @ $520	$1,040	PL-PF
(2)	PL-ER	2 days @ $570	$1,140	PL-ER
(3)	PL-H	2 days @ $570	$1,140	PL-H
(4)	EN-GB	2 days @ $570	$1,140	EN-GB
(5)	RE	2 days @ $570	$1,140	RE
(6)	Sponsor	2 days @ $520	$1,040	Sponsor
c.. Identify and evaluate intermediate alternatives.				
(1)	PL-PF	2 days @ $520	$1,040	PL-PF
(2)	PL-ER	2 days @ $570	$1,140	PL-ER
(3)	PL-H	2 days @ $570	$1,140	PL-H
(4)	EN-GB	2 days @ $570	$1,140	EN-GB
(5)	RE	2 days @ $570	$1,140	RE
(6)	Sponsor	2 days @ $520	$1,040	Sponsor
d. Identify/specify array of final plans.				
(1)	PL-PF	5 days @ $520	$2,600	PL-PF
(2)	Sponsor	2 days @ $520	$1,040	Sponsor
JJ PLAN FORMULATION AND EVALUATION:				
CORPS IN-HOUSE SUBTOTAL			$19,620	
SPONSOR SUBTOTAL			$ 4,160	
SUBACCOUNT TOTAL			**$23,780**	

[1]All costs are in December 1996 dollars.

*U.S. Army Corps of Engineers, Walla Walla District

PL-PF - Planning Division, Plan Formulation Branch
PL-H - Planning Division, Hydrology Branch
PL-ER - Planning Division, Environmental Resources Branch
EN-GB - Engineering Division, Geology and Dam Safety Section
RE - Real Estate Division

JJJ. THE EXECUTIVE COMMITTEE AND STUDY MANAGEMENT TEAM.

The Feasibility Studies will be managed by an Executive Committee and a Study Management Team, as provided in the Feasibility Cost Share Agreement (FCSA). The Executive Committee will oversee the overall study conduct, management, and Corps policy. The Study Management Team will include the Corps' Planning Study Manager, the Study Manager from the Sponsor, and other key study team members. The Study Management Team will oversee studies to ensure the establishment of desired mutual roles, interests, and study objectives. The Study Management Team will implement overall direction of the study provided by the Executive Committee and ensure that Corps' policy and the breakdown of tasks provided by the Project Study Plan (PSP) are followed. In addition, the Study Management Team will ensure that the study schedule and budget are maintained, sound technical judgment is followed, and a multi-disciplinary approach and decisions are made in accordance with applicable guidelines and policies. The Study Management Team will ensure that adequate input to the study process is received from all appropriate Federal, State, and local agencies, interested organizations, and individuals.

Program Subaccount Activity	Cost[1]	Responsible Element
a. Review by Executive Committee.		
(1) Corps of Engineers, 10 days @ $0	$0	CENPW
(2) Sponsor, 10 days @ $0	$0	Sponsor
JJJ EXECUTIVE COMMITTEE AND STUDY MANAGEMENT TEAM:		
CORPS IN-HOUSE SUBTOTAL	$0	
SPONSOR SUBTOTAL	$0	
SUBACCOUNT TOTAL	**$0**	

JJJJ. QUALITY ASSURANCE/QUALITY CONTROL PROCESS AND TECHNICAL REVIEW.

Quality assurance/quality control is an appropriate evaluation of technical products and processes to ensure they meet customer requirements and are in compliance with applicable laws, regulations, and sound technical practices of the disciplines involved. This includes an independent technical review to account for the level of risk inherent in the project. The degree of independence will be defined as part of the Quality Control Plan. Quality Control also involves early CENPW level involvement in the initial scoping process and also during the preparation stage of all technical documents. All levels within the CENPD Command are responsible for development and maintenance of effective Quality Assurance/Quality Control program. The following quality control plan has been developed per guidance in CENPD Technical Review Memorandum No. 1, 15 September 1995, subject: Technical Review Process - Quality Assurance, Quality Control (see34a).

QUALITY CONTROL PLAN

PRODUCT: Feasibility Report
TITLE: Jackson Hole Environmental Restoration
TYPE OF DOCUMENT: Civil Works (CW) Planning Study

DATE: February 26, 1996
PREPARER: W. MacDonald
TYPE OF REVIEW: Internal District

JJJJ QUALITY ASSURANCE/QUALITY CONTROL PROCESS AND TECHNICAL REVIEW:	
CORPS IN-HOUSE SUBTOTAL	$14,000
SPONSOR SUBTOTAL	$ 2,600
SUBACCOUNT TOTAL	**$16,600**

TECHNICAL REVIEW PROCESS - QUALITY ASSURANCE, QUALITY CONTROL

STUDY TEAM				REVIEW TEAM			
Name	Grade	Discipline		Name	Grade	Discipline	
W. MacDonald	GS-12	Plan Form/Team Lead	PL-PF	D. Smelcer	GS-12	Plan Form/Team Lead	PL-PF
R. Gay	Sponsor	Team Leader	SPONSOR	D. Barney	Sponsor	Team Leader	SPONSOR
C. Pinney	GS-12	Fishery Biologist	PL-ER	R. Jones	GS-12	Fisheries Biologist	PL-ER
R. Tracy	GS-11	Cultural	PL-ER	A. Shoulders	GS-12	Mechanical Design	EN-DB-SC
A. Carlson	GS-09	Env. Res. Spec.	PL-ER	P. Poolman	GS-12	Env. Res. Spec.	PL-ER
G. Ellis	GS-12	Economist	PL-PF	G. Trafton	GS-12	Economist	PL-PF
C. Sneider	GS-12	Structural Design	EN-DB-SC	L. Mettler	GS-12	Wildlife Biologist	PL-ER
F. Buerstatte	GS-12	Real Estate	RE	K. Pankaskie	GS-12	Cost Engineer	EN-CB
B. Ochsner	GS-12	Mechanical Design	EN-DB-ME	R. Carlton	GS-13	Real Estate	RE
R. Grubb	GS-12	Cost Engineer	EN-CB	D. Reese	GS-13	Hydrologist	PL-H
L. Cunningham	GS-12	Hydrologist	PL-H				

MASTER MILESTONE SCHEDULE

ACTIVITY	MILESTONE DATE
FCSA Signed	May 1996
Start Study	June 1996
AFB	August 1997
Draft Feasibility Report and EIS	June 1999
Feasibility Review Conference	July 1999
Final Feasibility Report and EIS	December 1999
Washington-level Approval	June 2000

JL. REPORT PREPARATION.

This account includes coordinating information from technical offices to be used in the drafting of a main report. Editing, revising, and printing of draft and final reports and other related documentation required for project authorization are also contained in this account. Reference: ER 1105-2-100, *Guidance for Conducting Civil Works Planning Studies.*

Program Subaccount Activity	Cost[1]	Responsible Element*
a. Coordinate CENPW report input		
(1) Study Manager, 30 days @ $520	$15,600	PL-PF
(2) Clerical Staff, 15 days @ $260	$3,900	PL-PF
(3) Printing and Reprographics (lump sum)	$10,000	PL-PF
b. Supervision and administration		
(1) Branch Chief Review, 5 days @ $570	$2,850	PL-PF
(2) Division Chief Review, 5 days @ $740	$3,700	PL-PF
JL REPORT PREPARATION:		
CORPS IN-HOUSE SUBTOTAL	$36,050	
SPONSOR SUBTOTAL	-0-	
SUBACCOUNT TOTAL	**$36,050**	

[1]All costs are in December 1996 dollars.

*U.S. Army Corps of Engineers, Walla Walla District
PL-PF - Planning Division, Plan Formulation Branch

JM. REVIEW, SUPPORT, AND REVISIONS.

Comments received on the draft Feasibility Report and EIS will be addressed and any revisions will be made to the final report. The Sponsor will be given the opportunity to participate in all significant rewriting, documentation, analysis, or reformulation required as a result of HQUSACE-level review. A "Review Support" work item will cover expenditures for any such activities. Should costs go beyond those provided under the review support work item, the FCSA will be modified to provide for 50/50 cost sharing of all additional costs. Any costs relating to the Feasibility Report that occur after the completion of the Feasibility Phase, with the exception of review support activities, will be 100-percent funded by the Corps, with cost sharing in accordance with the Project Cooperative Agreement (PCA). References: ER 1105-2-100, *Guidance for Conducting Civil Works Planning Studies;* EC 11-2-166, *Annual Programs and Budget Requests for Civil Works Activities*, and ER 1110-2-1150, *Engineering and Design for Civil Works Projects.*

Program Subaccount Activity	Cost[1]	Responsible Element*
a. Technical Review Conference (TRC).		
(1) Corps of Engineers	$1,880	PL-PF
(2) Sponsor	$940	Sponsor
b. In-Progress Review (IPR).		
(1) Corps of Engineers	$1,880	PL-PF
(2) Sponsor	$940	Sponsor
c. Review Draft Feasibility Report.		
(1) Corps of Engineers, 5 days @ $520	$2,600	PL-PF
(2) Sponsor, 2 days @ $520	$1,040	Sponsor
d. Revise Draft Feasibility Report.		
(1) Corps of Engineers, 10 days @ $520	$5,200	PL-PF
(2) Sponsor, 5 days @ $520	$2,600	Sponsor
e. Participate in Feasibility Review Conference.		
(1) Corps of Engineers, 10 days @ $520	$5,200	PL-PF
(2) Sponsor, 5 days @ $520	$2,600	Sponsor
f. Contingency for post-report issues.	$7,300	PL-PF
g. Provide review support.		
(1) Corps of Engineers, 25 days @ $520	$13,000	PL-PF
(2) Sponsor, 10 days @ $520	$5,200	Sponsor
JM REVIEW, SUPPORT, AND REVISIONS:		
CORPS IN-HOUSE SUBTOTAL	$37,060	
SPONSOR SUBTOTAL	$13,320	
SUBACCOUNT TOTAL	**$50,380**	

[1]All costs are in December 1996 dollars.

*U.S. Army Corps of Engineers, Walla Walla District
PL-PF - Planning Division, Plan Formulation Branch

JZ. FEASIBILITY LIFE CYCLE PROJECT MANAGEMENT.

a. Project Management Documents and Coordination.

Project Management Documents and Coordination is a management, coordination, and review product that will span the entire Feasibility Study Phase (assumed 3 years). Responsibility for managing the study parameters (cost, budget, schedule, scope, and quality) as well as interfacing with those involved in the study process (Sponsor, functional elements, Government and non-Government entities) will be vested in the Project Manager (PM). The PM will be the primary point of contact with the study Sponsor.

The PM, with support from CENPW and the Sponsor, will manage the Feasibility Phase from receipt of funds to begin the Feasibility Study to the President signing a bill into public law authorizing the project. The major products (level 3) of the Feasibility Phase include the Feasibility Report, Project Management Plan, and draft PCA. The PM will be responsible for coordinating closely with the Sponsor, the Study Management Team, CENPD, and HQUSACE to ensure that these products are on schedule, are on or under budget, have available funding, and that all necessary reporting requirements are fulfilled. The PM will also focus on the actual costs and performance, as compared to the cost estimates and schedule in this PSP and ensure that all variances are handled in accordance with ER 5-7-1, *Project Management*.

The following scope and estimate includes activities necessary to ensure that this study is being managed in accordance with the management principles and guidelines included in ER 5-7-1, *Project Management*.

The PM or a designated representative from CENPW Programs and Project Management Division will attend the following meetings planned for this study:

- Formal public involvement meetings.
- Steering Committee Meetings.
- Miscellaneous Meetings with resource agencies.
- Project Review Board Meetings.
- Pre-selection meetings for A/E contracts.
- Study Team Meetings.
- Feasibility Review Conference.

The PM will be involved with the substantive technical development needed in scoping the work packages, analyzing proposed scope changes, and ensuring that the deliverables of each work package fulfill the study commitments. Responsibility for the technical products and the methods of production are with the technical managers and the technical organizations. The project management team will be involved in the review and/or preparation of all documents prepared for this study. The following list includes the minimum:

- Expenditure /progress reports for Corps and Sponsor (R)
- Budget and Programming Documents (P)
- Funds Allocation Reports (P)
- Scopes of Work for Feasibility Phase (R)
- Public Involvement Information documents (R)
- Environmental Impact Statement (R)
- Feasibility Report (R)
- Pre-Conference Feasibility Report Conference (FRC) documentation (R)
- Economic Appendix (R)
- Real Estate Appendix (R)
- Engineering Appendix (R)
- Plan Formulation Appendix (R)
- Baseline Cost Estimate (R)
- Financing Plan (R)
- Initial Draft Project Cooperation Agreement (R)
- Project Management Plan (P) (**Note:** Costs for the PMP are separate from the project management documents and coordination costs.)

(P) - Responsible for Preparation (R) - Review

The Project Manager will review all Schedule and Cost Change Requests (SACCR's) and either approve or elevate to the appropriate level in accordance with ER 5-7-1, *Project Management* and the FCSA. To assist in early identification of schedule and cost deviations, the PM will use an earned value comparison. A cost and schedule for achieving each sub-product milestone will be established by the technical manager and reviewed and approved by the PM prior to allocation of funds for the sub-product. The ratio of the actual cost to the estimated cost will be the earned value ratio. If this ratio is greater than one, the PM will notify the appropriate Project Review Board (PRB) member(s) and the Sponsor and will take the lead in determining the corrective action to be taken. When a SACCR is submitted to the PM, the technical manager must include the new cost and schedule estimates for all milestones affected by the change; the new estimate will be used for earned value analysis after the approval of the SACCR.

Program Subaccount Activity	Cost[1]	Responsible Element*
a. Provide Project Management during the Feasibility Study		
(1) Project Manager, 40 days @ $720	$28,800	PM
(2) Cost Engineering Branch, 8 days @ $550	$4,400	EN-CB
(3) Travel	$4,500	PM
(4) Project Manager - 13.9 days @ $720	$10,000	Sponsor
MANAGEMENT:		
CORPS IN-HOUSE SUBTOTAL	$37,700	
SPONSOR SUBTOTAL	$10,000	
SUBTOTAL	$47,700	

[1]All costs are in December 1996 dollars.

*U.S. Army Corps of Engineers, Walla Walla District
EN-CB - Engineering Division, Cost Engineering Branch

b. <u>JL - The PMP</u>.

The PMP is a requirement of ER-5-7-1 for every Civil Works project. The PMP will be developed by CENPW and the Sponsor near the end of Feasibility Phase. It is a management plan that will guide the project through the Construction General Phase. It will provide a common understanding between the Sponsor and Corps with respect to the size and complexity of the proposed alternative; it will reduce uncertainties; and it will provide a basis for managing and monitoring the project. The PMP will establish scope, schedule, budgets, interface with the Sponsor, and technical performance requirements for the management and control of the proposed project. It will be a "living" document and will contain commitments between the Sponsor and Corps. The PMP will be comprised of the following elements or sub-products:

- JLAA Project Scope of Work
- JLAB Work Breakdown Structure (WBS)
- JLAC Organizational Breakdown Structure (OBS)
- JLAD Responsibility Assignment Matrix (RAM)
- JLAE Schedules
- JLAF Budgets and Cost Estimates
- JLAG Current Benefit Plans
- JLAH Resource Allocation Plan
- JLAI Project Cooperation Plan
- JLAJ Acquisition Plan
- JLAK Real Estate Plan
- JLAL Project Quality Management Plan
- JLAM Value Engineering Plan
- JLAN Safety Plan
- JLAO Security Plan
- JLAP Cultural Resource Plan
- JLAQ Environmental Plan
- JLAR Federal Emergency Management Agency (FEMA) National Flood Insurance Program
- JLAS Operation and Management (O&M) Plan
- JLAT Management and Control Plan
- JLAU Reporting Requirements Plan
- JLAV Change Control Plan
- JLAW PMP Appendix
- JLAX Coordination Documents
- JLAY All Other PM Documents

Development of the PMP will begin when the final alternative has been selected and the alternative plan design is completed. To initiate PMP development, the PM, who will have the lead role in the PMP development, will prepare the initial project scope in coordination with the Sponsor and the study manager of the Feasibility Report. The PM will arrange a series of workshops to finalize the project scope and develop the "foundation" elements of the PMP which are sub-products JLAA, JLAB, JLAC, JLAD, JLAE, and JLAF. The remaining vital elements

will be developed by assignment to various functional elements in the Corps. Sponsor involvement will be critical for all elements.

Once the PMP is assembled, a review will be performed by CENPW and the Sponsor. Functional elements within CENPW will have the opportunity to thoroughly examine scope, technical requirements, and resource commitments. Upon changes and corrections, the PMP will be furnished to the Sponsor for a final review and endorsement. Upon Sponsor endorsement, the PMP will be reviewed and approved by the CENPW PRB. Approval of the PMP will be an upward-reported milestone. The PMP becomes a "living" document.

The PRB approval of the PMP will constitute the "First Draft - PMP" which will be submitted with the Feasibility Report prior to the Feasibility Review Conference (FRC). Changes and adjustments to the PMP will likely occur due to the FRC, signing of the ROD, policy reviews, *etc.*, right up through project authorization by the President. The PM will coordinate this effort with the Sponsor and project team.

Program Subaccount Activity			Cost[1]	Responsible Element
b. Prepare Project Management Plan				
(1)	Project Manager	12 days @ $ 720	$8,640	PM
(2)	Clerical Support	5 days @ $ 300	$1,500	PM
(3)	Plan Formulation	6 days @ $ 520	$3,120	PL-PF
(4)	Economics	5 days @ $ 520	$2,600	PL-PG
(5)	Environmental Resources	7 days @ $ 450	$3,150	PL-PE
(6)	Hydrology	6 days @ $ 560	$3,360	PL-PH
(7)	Value Engineering	4 days @ $ 663	$2,652	VE
(8)	Geotech Branch	5 days @ $ 520	$2,600	EN-GB
(9)	Design Branch	2 days @ $ 490	$ 980	EN-DB
(10)	Cost Eng Branch	6 days @ $ 490	$2,940	EN-CB
(11)	Environmental Eng	2.5 days @ $ 490	$1,225	EN-EE
(12)	Real Estate Division	6 days @ $ 460	$2,760	RE
(13)	Operations - Emergency Management	3 days @ $ 490	$1,470	OP-EM
(14)	Construction Division	5 days @ $ 530	$2,650	CO
(15)	Contracting Division	5 days @ $ 350	$1,750	CT
(16)	Teton County	10 days @ $ 520	$5,200	Sponsor
(17)	PRB Approval and Reproduction	1 day @ $5,000	$5,000	CENPW
CORPS IN-HOUSE SUBTOTAL			$46,397	
SPONSOR SUBTOTAL			$5,200	
SUBTOTAL			$51,597	

Program Subaccount Activity	Cost[1]	Responsible Element
Project Management Documents and Coordination	$37,700	Corps
	$10,000	Sponsor
Project Management Plan (PMP)	$46,397	Corps
	$5,200	Sponsor
JZ FEASIBILITY LIFE CYCLE PROJECT MANAGEMENT:		
CORPS IN-HOUSE SUBTOTAL	$84,097	
SPONSOR SUBTOTAL	15,200	
SUBACCOUNT TOTAL	**$99,297**	

[1]All costs are in December 1996 dollars.

APPENDIX B

HYDROLOGY

OF THE

JACKSON HOLE, WYOMING, ENVIRONMENTAL RESTORATION FEASIBILITY STUDY

Hydrology Appendix B
Jackson Hole Environmental Restoration Study
Channel Improvement and Island Protection Measures

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Hydrology Appendix B
Jackson Hole Environmental Restoration Study
Channel Improvement and Island Protection Measures

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PLATES (Continued)

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PLATES (Continued)

CHARTS

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TABLES

APPENDIX B
Hydrology

1. PURPOSE AND SCOPE.

The purpose of this appendix is to provide technical support in the areas of hydrology, hydraulics, and geomorphology for the Jackson Hole Environmental Restoration Study. While the text provides a general overview of climate, streamflow, and erosional processes in the surrounding Snake River basin, the focus of the study is on four reaches of the Snake River in the Jackson Hole vicinity that were selected for detailed evaluation. Originally, 12 areas were selected for possible evaluation. However, due to time and cost considerations, the scope of the study was later reduced to include only the four areas that appeared to provide the greatest possibility for improvement. These areas (or "sites") are delineated on plate 1. Engineering Division, Hydrology Branch, studies were concerned with sediment transport and its effect on the proposed restoration measures, opportunities for increasing the stability of the river channel, survival of the proposed structures, and the effect of restoration measures on flood control.

2. PREVIOUS STUDIES.

Information on local flood problems and the performance of some early river training efforts were included in an interim report *Snake River and Tributaries above Milner Dam: Review Report*, dated November 4, 1947. Detailed hydrologic investigations were conducted for D.M. No. 1, *General Design Memorandum for the Jackson Hole Flood Control Project*, dated November 4, 1955, and for the unpublished *Jackson Hole Design Deficiency Report*, the review raft of that was dated September 25, 1975. Additional hydrologic information has been compiled at various times for the Committee on Channel Stabilization (CCS) and for numerous public meetings. The CCS met in 1974 and in 1987 specifically to address Jackson Hole levee concerns. A consultant report regarding channel stability and sediment concerns was prepared in 1987 by Northwest Hydraulic Consultants, Inc., of Kent, Washington. In 1975, the Walla Walla District performed a Snake River hydraulic study and presented the results in the report, *Special Flood Hazard Information; Snake River, Wilson, Wyoming, and Vicinity*, published in February of 1976. In 1985, Simons, Li, and Associates, Inc., under contract with the Federal Emergency Management Agency (FEMA), performed hydraulic studies of a number of streams throughout Teton County, including the Snake and Gros Ventre Rivers. The results were presented in the report, *Flood Insurance Study; Teton County, Wyoming, and Incorporated Areas*, released in May of 1989. In 1992, The US Army Corps of Engineers Waterways Experiment Station published a report, *Flow Impingement, Snake River, Wyoming: Miscellaneous Paper HL-92* by Steve Maynard, which documented velocity data which was collected during the peak of the 1991 runoff period at selected flow-impingement points within the Federal Levee Project reach. In December 1990, the Walla Walla District, Corps of Engineers completed a study of flood control measures including the possible levee

modifications and extensions. The results were published in the report, *Snake River at Jackson Hole: Hydrologic and Hydraulic Investigation, Teton County, Wyoming.* In June 1993, the Corps completed a Reconnaissance Report titled, *Jackson Hole, Wyoming: Flood Damage Reduction, Fish and Wildlife Habitat Restoration*. One of the major products of this report was a comparison of changes in vegetation types and distribution between 1956 and 1986.

Information has also been derived from numerous other publications. These include a background report prepared for the Teton County Planning Commission entitled *Teton County Growth and Development Alternatives*, dated May 1976; a technical bulletin prepared by John W. Kiefling for the Wyoming Game and Fish Department entitled *Studies of the Ecology of the Snake River Cutthroat Trout, dated 1978; the Water Control Manual for Palisades Reservoir*, maintained and updated yearly by the Walla Walla District; the *Water Resources Data, Idaho*, published yearly by the U.S. Geological Survey (USGS) in cooperation with the State of Idaho and with other agencies; and numerous interim reports published by the Walla Walla District and other Federal agencies. Information has also been obtained from the minutes of public meetings, conversations with the Walla Walla District construction and operations personnel, and with Don Barney and Conan Beasley of the Teton County Road and Levee Department. A ground water study, being performed by the State of Wyoming, in cooperation with Teton County, is in progress. It consists of continuous recording of the water level in a grid-work of observation wells located on lands adjacent to the Snake River. This should provide baseline data for future evaluation of the effects of projects on the surrounding nearby surface.

3. BASIN DESCRIPTION.

Jackson Hole is a valley about 10 miles wide and 35 miles long situated along the Snake River in northeastern Wyoming (see plate 1). The Teton Range bound it on the west, the high plateaus of Yellowstone National Park to the north, and the Gros Ventre Range to the east. Valley elevations range from about 5,900 feet at the Highway 26 Bridge over the Snake River to 6,800 feet in the vicinity of Jackson Lake, with an average elevation of about 6,200 feet in the Federal levee project area. Peak elevations rise to over 13,000 feet.

a. Major Streams.

The headwaters of the Snake River originate to the north in Yellowstone National Park. After passing through Jackson Lake, the river enters the Jackson Hole floodplain. Principal upstream tributaries are the Lewis River, Pacific Creek, and Buffalo Fork. The Gros Ventre River is a relatively large tributary, collecting runoff from a little over 25 percent of the total drainage area above the USGS gage site, "Snake River Below Flat Creek." It enters the Snake River from the east within the Federal levee project limits several miles upstream from the Jackson-Wilson Bridge. Fish, Flat, Mosquito, Cottonwood, Taylor, Squaw, and Spring Creeks are among the smaller tributaries that enter the Snake River in the vicinity of the four study areas. Flat Creek

enters the Snake River at the downstream end of the valley just below the Highway 26 Bridge.

b. Climate.

The climate of the area from Jackson to Moran, Wyoming, is typical of high elevation, Rocky Mountain valleys. During summer months the area has an abundance of sunshine with low humidity and high evaporation during the daytime. The growing season between killing frosts is limited by extreme diurnal fluctuations in temperature and resulting cold nights. Surrounding mountain areas seldom experience a month without freezing temperatures. Thunderstorms are frequent during the summer months, but individual occurrences affect only limited areas and resultant run-off in the Snake River and major tributaries is small in comparison to stream flows resulting from snowmelt.

Climatological records at Jackson show an average annual temperature of 38 degrees Fahrenheit (^{o}F) with period-of-record extremes of -52 ^{o}F and +101 ^{o}F. Temperatures as low as minus 63 ^{o}F have been recorded at Moran. Daily minimum temperatures below freezing usually occur at Jackson from early September to mid-June and freezing temperatures have been known to occur in any month of the year. The average frost-free period (growing season) is about 50 days at Jackson.

The Jackson Hole area is affected principally by moist Pacific maritime air masses brought into the region by prevailing westerly winds. As such, the valley is in somewhat of a rain shadow from the Teton Range. Frequently, cool polar air masses or warm continental air masses invade the region, displacing or modifying the effects of the maritime air masses. These latter types are mainly responsible for the clear weather, low humidities, and diurnal and seasonal temperature extremes. Jackson Hole is located just west of the Continental Divide, and, in addition to storms from the west, the Basin can be affected by orographic lifting of air masses from the north and east. During the summer, sub-tropical air from the southern Rockies can also be a source of moisture for thunderstorms.

The average annual precipitation varies from about 16 inches at Jackson to about 60 inches near the summit of the Teton Mountain Range. Minimum and maximum annual precipitation totals vary from about 60 percent to 150 percent of the mean annual precipitation, respectively. The 6-hour maximum rainfall for the 100-year storm is in the range of 2 inches $\pm$ 0.5 inch, and the 24-hour maximum rainfall is in the range of 3 inches $\pm$ 1 inch.

Precipitation is rather evenly distributed throughout the year in the valley, but more concentrated in the winter at higher elevations. Due to the cool temperatures of this high-elevation area, the precipitation accumulates mainly as snow from October through May. Average annual snowfall varies from about 80 inches at Jackson to over 300 inches at high mountain snow courses. Maximum annual snow depths vary from about 2 feet to over 10 feet, depending on the location. Maximum depletion rates of

snow normally occur during May and June, often resulting in flood conditions on the Snake River.

There are about six climatological stations in the Basin with long term records. Currently, the National Weather Service (NWS) maintains 10 climate stations providing daily readings in the Snake River drainage above Alpine and perhaps a dozen stations with similar climatic characteristics in nearby basins. Representative climatological information is given in table 1.

The National Resource Conservation Service (NRCS) maintains seven Sno-Tel stations in the upper Snake River Basin above Palisades Reservoir providing real-time snow water equivalent readings and limited temperature and precipitation information. As with the climatological stations, there are numerous additional stations in nearby basins that have good correlations with the Snake River sites.

The NRCS also coordinates and publishes semimonthly snow course measurements for 17 stations in the Snake River Basin above Palisades. About nine snow courses have long-term records, some of which are used by various agencies in conjunction with precipitation measurements in computing spring runoff forecasts. Representative snow course information is given in table 2. The NRCS will be phasing out most or all of its snow course measurements in future years as acceptable correlations with Sno-Tel sites become available.

4. RUNOFF ANALYSIS.

a. Runoff Patterns.

The Snake River and its tributaries in the upper Snake River Basin have regular patterns of natural seasonal flow with high flows during the months of May through July, receding flows in August and September, and low flows in the months of October through April. A summary hydrograph for the USGS gage "Snake River Below Flat Creek" is shown on chart 1. High flows in the late spring and early summer result from melting of the winter-accumulated snowpack sometimes augmented by rain storms. Winter flooding due to thawing conditions and rain-on-snow conditions can occur, but rarely result in damaging flows. For the period of record, maximum annual peak discharges have always coincided with the spring snowmelt season. Total annual runoffs for a given area vary with the amounts of precipitation received during the snowpack accumulation and the snowmelt seasons.

Regulation by the use of storage space in Jackson Lake reduces the Snake River flow during October through May and early June and augments Snake River natural flows during July, August, and September in order to satisfy downstream irrigation requirements. Regulation by Jackson Lake is discussed in greater detail in section 12 of this report.

Summer thunderstorms are common in the mountains. However, runoff from these storms tends to be highly localized, and Teton County authorities report that storm runoffs do not exceed damaging levels.

b. Discharge Records and Stream Gaging Stations.

The primary source for streamflow records is the USGS. Plate 2 depicts the current USGS hydrological reporting network in the upper Snake River Basin. In addition to the USGS published discharge data at various gage stations, inflow and release data is available from the U.S. Bureau of Reclamation for the Jackson Lake Dam and Palisades Dam projects.

The USGS has maintained a recording gage for the Snake River near Heise, Idaho, at river mile (RM) 854 continuously since September 1910. The listed drainage area is 5,752 square miles with a mean basin altitude of 7,770 feet. The average annual discharge for 76 years of record is 5,111,000 acre feet. The upstream storage projects at Palisades Reservoir and Jackson Lake, as well as numerous irrigation diversions regulate the flow. The Bureau of Reclamation computes the unregulated daily mean flows for the period of record, allowing for the effects of regulation.

A USGS recording gage for the Snake River below Flat Creek near Jackson, Wyoming, was established in November 1975. It has been maintained continuously since then. The gage is located at RM 938 about 1 mile below the Highway 26 Bridge and 4.8 miles above the Hoback River confluence. The drainage area above the gage is listed as 2,627 square miles with a mean basin altitude of 8,000 feet. The average annual runoff for the period 1977 to 1997 is 2,650,000 acre feet. Jackson Lake and several smaller irrigation diversions regulate the flow.

A USGS gage designated "Snake River Near Wilson, Wyoming," was operated for 3 years during the period October 1972 to September 1975. The gage was located near the Jackson-Wilson Bridge at RM 951. The basin mean elevation is approximately 8,000 feet. Due to the convenience of its location relative to the Federal levee system, the station period of record has been extended through correlations with other nearby gaging locations to cover the entire period 1904 to present. A correlation for the 1894 historical peak was also determined.

Various drainage areas for the Wilson gage have been published over the years. The USGS determined the drainage area to be 2,342 square miles and carried this figure in their annual streamflow listings. Based on this figure, one can also determine that the Snake River above the Gros Ventre River confluence has a drainage area of about 1,700 square miles. However, the Walla Walla District and other agencies had approximated the drainage area for the Wilson gage at 2,500 square miles prior to the 1970's. Based on the 2,500 square miles figure, the Snake River drainage area above the Gros Ventre River confluence was determined as 1,878 square miles.

A USGS gage for the Gros Ventre River at Kelly, Wyoming, was established in 1918. Continuous records were maintained only for the months of June to September of that year. The gage was restarted in October 1944 and was operated again through September 1958. Its drainage area is listed as 622 square miles with a mean altitude of 8,850 feet. The average annual runoff for 14 years of record was 344,000 acre feet.

In the fall of 1987, a new recording gage, given the name "Gros Ventre River Near Zenith, Wyoming," was established at Cattleman's Bridge on the Gros Ventre River just upstream of the Snake River confluence. A USGS gage with a similar name was operated intermittently just downstream of the current location during the years 1917 and 1918. Its drainage area was determined to be 683 square miles, with a mean basin elevation of 8,800 feet. The average annual discharge of the new gage should be similar to that for the Kelly location. Summer and fall flows at the Zenith location are significantly reduced by upstream irrigation diversions. September flows during 1988 dropped to 1 to 2 cubic feet per second (cfs) on most days.

Since September 1903, the USGS has continuously maintained a recording gage on the Snake River near Moran, Wyoming. The gage is located at RM 989 just below Jackson Lake Dam. The drainage area is 807 square miles, with a mean basin elevation of 8,040 feet. The average annual discharge for 94 years of record is 1,047,000 acre feet. Jackson Lake regulates the river flow at the gage.

In addition to the locations listed above, gages have been or are being maintained on Pacific Creek near Moran; Buffalo Fork near Moran; Buffalo Fork above Lava Creek near Moran; Cache Creek near Jackson; and the Hoback River near Jackson. Limited discharge records are also available for Spread, Spring, Cottonwood, Fish, Mosquito, Big Spring, Flat, and Horse Creeks.

Of the 2.65 million acre feet average annual runoff for the "Snake River Below Flat Creek" gage site, 38 percent originates upstream of Jackson Lake Dam, the Gros Ventre River contributes 12 percent, Pacific Creek and Buffalo Fork provide an additional 22 percent, and the remainder comes from smaller tributary streams between Jackson Lake Dam and the Flat Creek gage. The fact that Jackson Lake contributes less than one-half the runoff at the Flat Creek gage is significant in evaluating the potential benefit of using Jackson Lake regulation for flood control.

c. Ground Water.

The porous and unconsolidated alluvial and glacial deposits are the major aquifers in Teton County. Much of the floodplain is close to the level of the river and laced with abandoned or relief channels. Due to the ready exchange of water between the river and the aquifer, channels that have been abandoned or cut off by levees often still contain flowing or standing water. Along the Snake River and its major tributaries the aquifer can supply very large amounts of water. Water tables are often less than 5 feet below the ground surface for a significant portion of the year. Ground water

levels, reflecting the surface runoff patterns, are highest in the spring and early summer and lowest later in the fall and early winter.

Local authorities and Walla Walla District construction personnel report that spring-fed water courses will rise in tandem with the snowmelt runoff in the main streams, but the increase in flow is of a much lesser magnitude and does not seem to approach damaging levels.

Ground water and surface-water levels were monitored for a 1-year period in 1991 along several cross section lines on the right bank of the Snake River below the Jackson-Wilson Bridge. In this area, the ground water fluctuated in tandem with the level in the Snake River, with the magnitude decreasing with distance from the river. Ground water levels upstream of the bridge have been studied in much greater detail by the State of Wyoming using an extensive network of continuously-recording observation wells. The results of this study, when available, should provide a much better understanding of the connection between surface water and ground water levels.

d. Irrigation.

Numerous irrigation diversions off the Snake River and other major tributaries are protected by water rights. It is sometimes claimed that the rates of withdrawals are greater than permitted by the water rights. Apparently, this occurs when irrigators concentrate the application of their seasonal appropriation during relatively short time periods. Total withdrawals are likely to be less than the adjudicated allocation.

Diversions can have significant impacts. As an example, during low water years, the total flow is diverted from the Gros Ventre River in late summer and fall, leaving the lower 3 miles down to the Snake River confluence dry, except for a small amount coming from ground water springs and irrigation return flows.

The irrigation season generally lasts from about 1 May to 1 October. There are currently eight active diversions within the Federal Levee Project area and an additional eight inactive diversions. Some of the diversion headworks serve more than one canal. The headworks are typically concrete with hand operated slide gates. Downstream of the Federal project levees, there is a major diversion behind the Upper Taylor Creek Levee, a major diversion through the Federal Levee Extension, and a minor diversion at the upstream State Game and Fish Levee. The two major diversions are for irrigation, and the minor one provides a dependable supply of water to a downstream spawning channel tributary to Flat Creek. There are no active diversions in the vicinity of the non-Federal levees along the lower reaches of the Gros Ventre River. However, there is a major diversion along the left bank of the Gros Ventre River just upstream of the Grand Teton National Park boundary. There is also a back channel on the right bank of the Gros Ventre River above the non-Federal levee area from which numerous diversions are made, including some into the country club and golf course developments.

Once Jackson Lake is filled by the spring runoff, Jackson Lake Dam passes inflow. Releases above the level of inflow commence when required by those holding irrigation storage rights. In general, elevated flows last all summer and taper off to minimum releases in September or early October.

5. FLOOD CHARACTERISTICS.

a. General.

Flood characteristics of the Snake River are typical of a highly braided stream. Due to the high transport of bed load the channel-bed complex is constantly changing. During high flows, avulsion of the main channel into side channels is common. When the flow erodes a gravel bar or the main channel becomes clogged with debris, the flow can shift direction suddenly and unpredictably. Flow velocities in both the main channels and the back channels tend to be high due to the general steepness of the valley. Flood damages include water damage from inundation, loss of land due to bank erosion, and damage to levees due to erosion or undercutting. Before the levees were constructed, flood damages in unleveed reaches began at flows of 5,000 cfs and became significant as flows increased to the 8,000 cfs to 10,000 cfs range. With the current levee system in place, significant damage now begins in the non-Federal reaches with flows in the range of 11,000 cfs. However, bank materials are often so low in resistance that erosion can continue, to some extent, even during low flows.

Many of the existing levees were constructed in response to perceived threats arising from avulsion of the main channel. As an example, there was great concern in the 1940's and 1950's that the Snake River was tending westward, posing a major threat to the town of Wilson and upstream developments. There has also been continuing concern that the river could eventually capture the lower reaches of Fish and Flat Creeks. Capture of Fish Creek is prevented as long as the Federal levees are adequately maintained. Capture of Flat Creek would harm the elk habitat area, damage spawning channels, and also endanger the Highway 26 Bridge. In the vicinity of the Gros Ventre River confluence, avulsion of both the Snake River and Gros Ventre River main channels is endangering spawning channels in the Three Channel Spring Creek study area. Bank erosion and channel scour was particularly evident following the 1986 flood. Extensive levee repairs were required during and after that flood, and, in addition, Teton County requested assistance for clearing and snagging operations in the main channels of both the Snake and the Gros Ventre Rivers. In response, a Federally funded, low-level clearing and snagging project was completed in the fall of 1989.

b. Peak Flows.

Due to the convenient location of the "Snake River Near Wilson" USGS gage, both regulated and unregulated annual peak discharges have been determined for this station for the period from 1904 until the Wilson gage was established in 1972. Unregulated (natural) peaks were computed by determining what the flood peaks would

have been naturally without flood control operations and irrigation storage at Jackson Lake. For years when the gage was not operated, estimations of regulated peak discharges were made based on the records of relatively nearby USGS gaging stations, and from estimated or gaged spot flow measurements on tributary streams. The Wilson gage was discontinued in 1975 and a new gage was established about 13 miles downstream at a location below Flat Creek where channel geometry was more stable. Although there are a number of small tributaries entering the Snake River downstream, including Flat Creek, the peak flow data from the new gage location has generally been used, without adjustment, for the Wilson area.

In addition to the computed period of record 1904 to present, an estimate of the 1894 flood peak was made for the Wilson location based on correlations with records for the "Snake River At Idaho Falls, Idaho," gage location. The 1894 flood was the largest in recent history for streams in the Northwest, disregarding the 1927 flood resulting from the Lower Slide Lake failure.

Floods exceeding 10,000 cfs occurred 83 times between 1904 and 1988, and discharges exceeding 20,000 cfs have occurred 15 times. Major floods resulting from normal snowmelt are indicated in the following tabulation (estimated annual peak discharges):

Year	Peak Flow (cfs)
1894	41,000
1918	32,500 *
1997	32,000 * **
1904	28,500
1909	25,900 *
1986	25,600 *
1996	24,800 *
1917	23,400 *
1927	22,900 *
1943	22,800 *
1911	21,900 *
1982	21,800 *
1913	21,200 *
1914	20,700 *
1928	20,700 *
1912	20,200 *
* Flows partially regulated by Jackson Lake Dam. ** An unofficial reading of 32,027 was observed on this date. The official USGS data lists only the mean daily value of 30,200 cfs.	

c. Flood Frequencies.

(1) Gros Ventre River Near Kelly.

The frequency curves for the "Gros Ventre River Near Kelly" gage location are based on an analysis of (1) actual data of the "Gros Ventre River At Kelly USGS" gage for the period of record 1918 and 1945 to 1958, and (2) an extended record 1904 to 1978 developed using a regional frequency analysis. Based on these computations, the 100-year flood event on the Gros Ventre is 6,600 cfs. The frequency curves are shown on chart 2.

(2) Snake River Below The Gros Ventre River Confluence.

The Walla Walla District previously analyzed the Snake River frequency curves in 1975, as published in the 1976 report, *Special Flood Hazard Information; Snake River, Wilson, Wyoming, and Vicinity*. The same curves were used for the unpublished 1975 report, *Jackson Hole Design Deficiency*. The additional data now available has been added to the previous data in computing new curves used for the current study. The approach applied to the analyses of the unregulated (natural) discharge frequency curves is similar in both instances.

Frequencies were re-evaluated in 1987. The 1987 analysis of the unregulated (or "natural") annual peak flow series for the "Snake River Near Wilson" gage location resulted in expected probability discharges which are only slightly changed from the discharges shown for similar recurrence intervals by the 1975 curves. As an example, the unregulated 500-year flood discharge indicated by the 1975 curve is 45,000 cfs compared to the 1987 curve value of 44,300 cfs.

The present analysis was based on 83 years of systematic record (1904-1987) extended to include the 1894 historical peak (41,000 cfs). A log Pearson Type III curve was fit to the data using an adopted skew coefficient of -0.2.

It has become evident that the degree of regulation indicated by the 1975 regulated frequency analysis has not always been realized. An updated 31-year series for the period 1956 to 1986 was used for the current frequency curve. The available data was plotted on standard log probability paper and the frequency curve was drawn to provide a graphic best fit. For floods with average recurrence intervals of 10 to 100 years, a constant 25 percent reduction in the unregulated flows was assumed, due to the effects of Jackson Lake regulation. This appeared to be a reasonable reflection of available data. To check the 25 percent reduction assumption, a separate frequency analysis was performed on the same data, utilizing the log Pearson Type III distribution and an adopted skew of -0.2. The computation resulted in a 100-year expected flood of 26,800 cfs, compared to a value of 28,600 cfs derived from the best fit curve. Due to the uncertainties inherent in future regulation, the more conservative best fit curve (28,600 cfs 100-year flood) was adopted for the 1987 study. Since that uncertainty increases excessively at the 500-year flood level, regulation was assumed to be ineffective at the 500-year recurrence interval. It should be noted that the 28,600 cfs value for the regulated 100-year flood is considerably higher than the value of 23,300 cfs that was derived in 1975 and used for Flood Insurance Studies in this area. Although 28,600 cfs is considered more accurate, the 23,300 cfs value was used in the Hydraulic Analysis section of this report when making comparisons with flood profile information in the Flood Insurance Study.

The frequency curves determined in the 1987 re-evaluation represent the best estimate at the present time. Since these frequency curves were developed for use at the reconnaissance level, additional evaluation may be required in the future. Unusual and unpredictable events such as the landslide-related Gros Ventre flood of 1927; dam failures such as the Teton Dam collapse; or the effects of earthquakes on control structures, were not included. The frequency curves for both the natural and regulated floods are shown on chart 3 for the Snake River near Jackson, Wyoming. These curves represent the discharge-frequency relationship for the Snake River below the mouth of the Gros Ventre River.

(3) Snake River Above The Gros Ventre River Confluence.

Only the regulated peak discharge frequencies were recalculated in 1987 for the Snake River study reach above the Gros Ventre confluence. A correlation was initially computed between the probable (actual, if available) Gros Ventre River discharge on the day when peak flows on the Snake River were occurring. It was found that the Gros Ventre River discharge tended to be about 90 percent of the Gros Ventre River peak discharge predicted for that year based on the 1986 Gros Ventre River frequency curves. Therefore, the regulated flow frequency curve for the Snake River above the Gros Ventre River confluence was plotted as equivalent to the Snake River near Jackson curve reduced by 90 percent of the peak flow indicated by the Gros Ventre River frequency curves for a given recurrence interval. The regulated frequency curve for the Snake River upstream from the Gros Ventre confluence is shown on chart 4. Peak flood discharges for selected recurrence intervals at this and other locations are listed in tabular form on table 3.

d. Winter Ice Conditions.

The Flat Creek reach from the town of Jackson to South Park Road is subject to local flooding resulting from ice blockage in the winter months. The problem is apparently related to low flows and velocities in this stretch of Flat Creek. Several days of below zero weather can completely freeze the creek locally. With milder weather, the flow is reestablished over the top of the ice. Additional cycles of freezing can result in overtopping of the low banks, resulting in hazards to livestock and agricultural facilities in the area. Local residents attempt to break up ice blockages to minimize damage, but such efforts do not always prevent flooding. Depth of flooding may reach 2 to 3 feet on flat land during the period December to March, but flow velocities are apparently very low. Flat Creek is the only stream in the region known to flood in this manner.

The Snake River has experienced ice jam flooding downstream in the Idaho Falls area, and some ice accumulations in the canyon downstream of the Hoback confluence, but flow velocities in the Jackson Hole reach appear to be high enough to prevent its occurrence there. Accumulations of frazil ice on the bed (anchor ice) and shore-ice at the surface have been noted on the Gros Ventre River, with detrimental effects on winter trout habitats.

e. Flow Velocities and Levee Impingement.

The U.S. Army Hydrologic Engineering Center (HEC) modeling (HEC-2) accomplished for previous floodplain studies have indicated that flow velocities, averaged across the channel, during 100-year flood events vary from 2 to 11 feet per second (fps) on the Snake River studied reaches and from 4 to 9 fps on the Gros Ventre River studied reaches. Velocities for various flood frequencies within the four selected study areas are indicated on tables 10-17.

Field observers have noted that local velocities were much higher at points affected by log jams, flow over riffles and rapids, and at levee impingement points. The

majority of the damage to the levee sections often appears to occur during the recession from the flow peak. It is likely that high flows, which override the gravel bars and low-flow meander loops, leave the channel bed clogged with debris and gravel. As the water level drops, the flow follows the path of least resistance where it may be directed against undisturbed land along the bank line. The flow may back up on one side of the channel, then flow rapidly down a steep incline toward the opposite side of the channel. These impinging flows can reach very high velocities, undermining trees, damaging or undercutting levee protection, and resulting in high levels of bank erosion in nonleveed reaches.

During May and June of 1974, velocity profiles were obtained at a number of impingement locations along the Federal project levees. During that particular flood event, it was estimated that high intensity impingement flows affected on the order of 5 to 10 percent of the Federal project levee length. Measurements were taken adjacent to the riprap at various depths with a river discharge of 13,790 cfs. The measurements are summarized in table 4. Flow velocities of 10 fps were common at high intensity impingement locations, including points immediately adjacent to the riprap toe.

During the 1991 runoff season the Corps of Engineers Waterways Experiment Station collected water-surface profile data and measured impinging velocities at eight different locations within the Federal Project reach (see plate 3). The results of this study are documented in a September 1992 report: *Flow Impingement, Snake River, Wyoming, Miscellaneous Paper HL-92*. Flows during this period varied from 14,000 to 16,000 cfs, which correspond to a 2- to 3-year peak flow event. The results were too extensive to reproduce in this report; but a sample of the data, taken at three locations, is reproduced on plates 4-12. It should be noted that the high velocities resulted from the flow escaping from a high point on one side and then accelerating across the channel to a low point on the other, where it impinged on the levee embankment. The maximum water-surface slopes in these cross channel currents were up to 80 feet per mile. In contrast, the average slope of the river was about 19 feet per mile. Results of this study indicated that depth averaged velocities could reach 12 fps in the impingement zone near the levees, and point velocities farther out could occasionally reach 16 fps. Velocities of 8 to 10 fps within 2 or 3 feet of the riprap face were very common at impingement locations. Scour depths of up to 15 feet below the water surface were measured in some locations.

It has been noted that flow tends to override many of the gravel bars and low-flow channel features during peak flow conditions and that the angle of attack may not be as severe during major floods as during lesser events or during the recession period. Under these conditions impingement velocities would not necessarily increase in proportion to the magnitude of the flood discharge. Structures in the path of the active flow would be exposed to flow parallel to the levees, with velocities which tend to increase in proportion to the discharge; while also being exposed to possible attack from cross channel impinging flows, with high velocities concentrated in a small area.

6. RIVER AND BASIN GEOMORPHOLOGY.

a. General.

The topography of the Jackson Hole area is influenced by tectonics (fracturing, tilting, and folding of the earth's crust), by glaciation, and by the action of the Snake River and its tributaries. A major fault zone defines the western edge of the Jackson Hole valley, extending from Moose south past Hoback. Jackson Hole is formed by the uplifting of the Teton Mountain range to the west of the fault line and the downward displacement and westward tilting of the Teton plate fault block to the east. A deep deposit of alluvial material overlain with glacial outwash gravels now covers this discontinuity and forms the floor of the Jackson Hole valley (see plate 13).

Nearly all of the large natural lakes in the area were formed behind the terminal moraines left by prehistoric glaciers. Jackson Lake, located on the Snake River 38 miles upstream from the city of Jackson, is, by far, the largest of these natural bodies of water, with a volume of 847,000 acre feet, a depth of over 400 feet, and a length of 20 miles. Outwash from the large glacier at the Jackson Lake location, smaller nearby glaciers, and sediment from tributary streams is distributed downstream, forming a steeply sloping valley floor. Variations in vegetation, as seen on aerial photographs downstream of Jackson Lake Dam, clearly show the patterns of a highly-braided flow that probably extended across the entire width of the valley during glacial recession. Similar patterns can still be seen in outwash from receding glaciers in the Columbia Icefields of Canada.

Outflow from Jackson Lake escapes around the eastern side of the terminal moraine at the present location of Jackson Lake Dam. Episodes of meander belt widening and channel down-cutting have left several terrace levels stepping down to the present active channel bed. The channel entrenchment reaches a maximum depth of about 160 feet near Deadman's Bar (about 16 miles downstream of Jackson Lake Dam). The depth of entrenchment decreases and the width of the floodplain increase as one moves farther downstream. Finally, somewhere in the vicinity of the Gros Ventre River, the terraces disappear and the channel emerges on the surface of the valley. Numerous relic channels and secondary branches can be seen in aerial photographs. These often become active during high-flow periods, allowing flood flows to escape the main Snake River channel and fan out across the valley floor.

Downstream from the Gros Ventre confluence, several features suggest that the river channel has been aggrading: flat or convex valley cross sections, low or poorly defined channel banks, a wide meander belt, old channel scars indicating widespread shifting of the channel in the past, and tributary streams which turn abruptly on entering the valley and then flow parallel to the Snake River.

A contributing factor, possibly influencing the parallel flow of tributary streams on the west side of the valley, is tectonic tilting of the Teton fault block. The gentle, but measurable, westward slope of the terrace surfaces, and the absence of alluvial fans along the western edge of the valley, suggests that tilting of the valley floor may still be

in progress. Some concern has been expressed that the river, if unrestrained, might suddenly shift westward into the lower Fish Creek Channel, permanently flooding the town of Wilson and surrounding developments. However, it could be argued that the river would have escaped its present channel and become permanently trapped against the eastern toe of the Tetons long ago if tilting were the predominant influence. The river has, in fact, overflowed into these areas during past floods. However, any sudden changes in the slope of the valley floor, resulting from earthquake activity, could result in major changes in the path of the Snake River. The Jackson Hole area is considered to be a highly active region.

Heavy rainfall in 1925 saturated steeply sloping soils on the canyon walls along the Gros Ventre River resulting in a major landslide that blocked the Gros Ventre. Failure of the natural dam in 1927 created a brief flood that destroyed the town of Kelly, destroyed several bridges, and washed a large quantity of gravel and other debris into the Snake River. Although peak flow has not been determined (it reached an estimated 60,000 cfs 100 miles downstream at Heise), it exceeded anything on record for the Snake River at Jackson. While the immediate effects were disastrous, there is ample evidence that similar events have occurred in the past. Upper Slide Lake (about 8 miles upstream) was created by a smaller slide in 1908, and almost continuous slide scars can be seen on some parts of the canyon walls along the Gros Ventre River.

There has been considerable conjecture concerning the effect of the influx of gravel into the Snake River from the Gros Ventre slide. A large influx of gravel would be expected to shift the Snake River channel to the West and increase the braiding and instability of the river channel downstream. Engineering drawings, dating back to the late 1930's, suggest that there might have been some remnants of an alluvial fan at the mouth of the Gros Ventre at that time. However, the Snake River has cut away any evidence of a fan and has recently been shifting to the east in this area. The absence of an alluvial fan at the mouth of the Gros Ventre, the absence of a major change in channel slope, or braiding pattern would seem to indicate that it is not presently discharging enough gravel to have a dominant effect on the regime of the Snake River.

b. <u>Stream Gradients</u>.

The gradient of the Snake River from Cabin Creek to Jackson Lake Dam is shown on plate 14. The steepest section of this river is the reach from Moose Bridge downstream to the end of the Federal Levee Project. Beginning at Jackson Lake, the gradient of the Snake River gradually steepens from a minimum of 4 feet per mile at Jackson Lake Dam to a maximum of 21 feet per mile at the upstream end of the Federal Levee Project. The gradient through the levee project is nearly constant, but then begins to gradually flatten out downstream, reaching a minimum of 11 feet per mile at the confluence with Flat Creek. Then it remains constant for the next 11 miles downstream.

The first 11 miles from Jackson Lake Dam to Spread Creek is a relatively quiescent stream, with an average gradient of less than 5 feet per mile. Although there

is some braiding just below Buffalo Creek, most of the channel exhibits the characteristics of a meandering stream. The mild gradient appears to be controlled both by the geometry of the terminal moraine of Jackson Lake and Spread Creek Alluvial Fan. The river passes through a narrow cut about 500 feet wide and over 160 feet deep at Deadman Bar, located about 16 miles downstream of Jackson Lake Dam. From there the gradient continues to steepen and the character of the river alternates from meandering to braided. High terraces rise on both sides of the 3,000 to 4,000-foot-wide meander belt.

A 2-mile reach of the river at Moose Bridge is confined in a single channel and has been surprisingly stable for the last 100 years. The channel is highly braided upstream of this location and then converges to a single, stable channel with a well-armored bed for the next 2 miles downstream. There has been considerable discussion regarding the cause for this sudden change. Blacktail Butte to the East and high terraces on both sides sharply neck the valley down at the exact point where the river regime suddenly changes. Two streams also converge into the Snake River at this point.

A short distance downstream of Moose Bridge the confining terraces disappear and the stream changes back to a highly braided channel, remaining braided until it enters the canyon downstream of the Highway 26 Bridge. Below the bridge it reverts back to a meandering regime within the narrow confines of the surrounding mountains.

It is generally known that an increase in either mean discharge, channel slope, or bed load supply tends to shift a meandering river toward a more unstable or braided character. After analyzing data from many sand bed streams, Lane observed that these streams tended to be braided when the value of channel slope multiplied by the one-fourth power of the mean annual discharge ($SQ^{0.25}$) exceeded 0.01 (*Sediment Transport Technology*, Simons & Senturk, pg. 36,37). The mean annual discharge of the Snake River just below Jackson Lake Dam is 1,470 cfs, while at the gage below Flat Creek it is 3,665 cfs. On the Snake River in the leveed reach $SQ^{0.25} = 0.038$, while upstream near Jackson Lake Dam the value drops to 0.006. Although the Snake River in this reach is a gravel bed stream it probably follows a similar relation, leading to the conclusion that the change in channel slope alone probably explains why the leveed reach is braided, while some reaches farther upstream exhibit meandering characteristics. This relationship between slope, discharge, and bed load further suggests why the channel follows a somewhat meandering pattern during low flow periods but reverts to a highly braided pattern during the spring runoff period. It also explains why some of the smaller tributary streams exhibit a meandering pattern. Jackson Lake influences the channel regime in the upper part of the river by removing all but the finest suspended sediment from the water. All of the bed load in the lower river is derived from tributary streams and from erosion of the channel and channel banks downstream of Jackson Lake.

The natural riverbed in the study reaches consists of an active zone 400 to 1,500 feet wide, which is kept vegetation free by bed load movement and the erosive action of the constantly shifting, braided river channels. From this central zone, numerous smaller channels branch off and spread out through the forested floodplain similar to the branches of a tree. These secondary or relief channels eventually rejoin the main channel some distance downstream. During the low-flow period, which usually extends from August through April, the secondary channels are often dry or derive flow from ground water seepage. During high flow periods the main channels fill and then spill over into these secondary channels, spreading the flow out over a wide area of the floodplain. The valley floor consists of a thin layer of topsoil underlain with a substrate consisting of cobbles mixed with sand and gravel. Although the roots of willows and cottonwoods provide some binding action, the rounded gravels are very easily eroded and provide very little resistance to lateral shifting or widening of the channel. The river randomly changes course, sometimes carving a loop out of the forested banks, and at other times cutting a new course along an existing secondary channel. In some areas, the river appears to alternately follow one channel and then another during successive flood periods.

c. Effect of Levees.

(1) Visual and Physical Impacts.

There has been considerable interest in obtaining reliable data on the long-term effects of the levees on the valley, both with respect to changes in vegetation and overall channel-bed erosion.

Due to the unstable nature of the river, loss of land through avulsion and bank erosion has been a major concern to communities and property owners in the valley. In an attempt to protect their property from flooding and reduce erosion losses, local interests have constructed a variety of flood- and erosion-control structures. Prior to 1955, levee and bank protection works consisted mostly of small, discontinuous structures designed to block flow into a secondary channel, protect a bridge approach, or limit erosion on the outside of a channel bend. With time these projects became more numerous, and included a wide variety of rock and timber crib dikes, fences, and channel plugs. In 1964, the Corps of Engineers completed a major levee project that provided a nearly continuous system of levees along a 13-mile reach extending upstream and downstream of the Jackson-Wilson Bridge. These levees are referred to as the Federal Project or Federal Levee Project in the remainder of this report. Although the maintenance costs have been high, these levees have prevented considerable flooding and erosion losses during the 30+ years since construction. In 1997, they successfully carried a flow of 32,000 cfs, which was well above the estimated, 100-year flood level. Additional levee extensions and levee sections were built during the succeeding years both by the government and private landowners. Many of these projects were built during flood-fight efforts.

To the degree that these levees have blocked the lateral spread of the Snake River, they have tended to reduce the width of the floodplain and the degree of randomness of the braided system. Channel migration and avulsion activity has been limited to the area between the levees, concentrating the discharge in the existing main channels and increasing the frequency of attack on vegetated areas between the levees. Flow in the main channels could not stray beyond the bounds of the levees; and the secondary channel branches were blocked at the levee boundaries, limiting the spread of flood flows and lateral movement of sediment. Channel-bed gravels were reworked more frequently. Bed materials, brought into suspension by the turbulent flow, were more likely to be carried through the system rather than being carried laterally into the slower secondary channels where they could be redeposited over a wider area of the floodplain. The levees created an unnatural visual impact by blocking, and then redirecting flow along an engineered curve conforming to the contours of the flood-control structure. In addition, the levees created a sharp, visual line of demarcation separating areas of undisturbed vegetation on one side of the levees from erosion and expanses of bare gravel on the other.

A series of sediment ranges were established in 1954 and then resurveyed 1967, 1973, and 1988 to document erosive changes in the channel bed. In addition to providing documentation on major channel changes, periodic resurveys of these ranges provided a means for calculating the volume of sediment lost or gained in different reaches of the river. These surveys covered only the Federal Levee Project that extended down approximately to Mosquito Creek. The location of these ranges is indicated on plate 15. Below this reach, surveys in 1973 and again in 1988 provided some information. However, there were uncertainties in the location of these surveys; and the distance between the surveys was too great to serve as a basis for accurate calculation of eroded volumes.

(2) Erosion Losses Resulting from Levee Construction and Other Factors.

Using the average change in channel-bed elevation to indicate erosion or deposition, the gains or losses in bed material were graphically depicted for the reaches between each of the surveyed ranges throughout the project. Bed material losses represented by an average vertical change in the channel bed for 1954 to 1967 are indicated on plate 16, 1967 to 1973 on plate 17, and 1973 to 1988 on plate 18. Losses for the entire 33-year period are indicated on plate 19. The change in channel thalweg (as measured by the lowest point on the cross section) is indicated on plate 20. During the 1954 through 1967 period, erosion was very heavy, with most occurring between the Jackson-Wilson Bridge and the Gros Ventre Confluence. A 2-mile reach above the Gros Ventre and a short reach above the Jackson-Wilson Bridge experienced aggradation. During the next 6 years, the areas of aggradation and degradation tended to be the opposite in several critical areas such as near the upstream and downstream ends of the levees and upstream of the Jackson-Wilson Bridge and the Gros Ventre confluence. The final 15-year period again exhibited a tendency toward alternate areas of erosion and degradation in a pattern nearly opposite to the previous period.

Alternating areas of erosion and deposition are probably characteristic of the random nature of the process in a braided stream. The overall trends are more significant than short-term changes. Some erosion losses and sedimentation gains can be expected even under natural conditions.

The volume of erosion during the 33-year period (1954 to 1988) was heavily influenced by heavy erosion in the early years following the completion of the levees. To an unknown extent, material borrowed from the riverbed during levee construction also contributed to the calculated losses. During the 33-year period, a calculated volume of 3.1 million cubic yards (mcy) of material was lost from the project reach. The loss was greatest during the early years of the project (1954 to 1967), tapered off a little during the next 6 years, and then dropped off considerably during the 1973 to 1988 period (see plate 21). If this trend is representative, it would suggest that the leveed reach is moving toward a stable condition in which the volume of erosion is balanced by an equal volume of deposition. The overall loss of material during the 34-year period, if spread out evenly over the entire area between the levees, would lower the channel bed about 0.85 feet.

An in-depth study of the reasons for erosion in one area and deposition in another would require more time than is available for this study. However, comparison of these graphs with the pre-project river indicates that the greatest erosion has occurred where the levees had the greatest impact on the pre-project flow patterns during flood conditions. For instance, the area of deposition upstream of the Gros Ventre River corresponds to an area where no levees exist on the left side of the river, and levees on the right generally follow the active meander boundary. Downstream of the Gros Ventre, where the heaviest erosion took place, levees crowd the river to the East cutting off about one-half of the active meander belt width. Gravel pits now occupy the area where the river once expanded during flood seasons. A similar constriction of the floodplain exists downstream of the Jackson-Wilson Bridge where flows historically escaped to the west. Levees cut off a main alternate channel and other smaller braided secondary channels, confining flow to a much narrower corridor to the East.

Considerable sediment movement has probably occurred since the last complete survey in 1988. In Area 10, for instance, the 1996 surveys indicated that more than 400,000 cubic yards (cy) of material may have been lost in this area alone since 1988 (see table 18). The flood of 1997, which peaked at the highest flow since 1918, probably moved a considerable amount of gravel and rearranged the channel-bed geometry. Fieldwork on a 1998 partial resurvey of sediment ranges downstream of the Federal Project Levees was completed and the results were being processed and reviewed as this report was in the final stages of completion. This survey extends through portions of Areas 1 and 4. Preliminary results suggest that major channel changes and gravel movement has occurred since the last survey in these areas.

The above information does not give a complete picture of the total sediment transport process; only the net change between surveys. Over plots of

successive range surveys indicate that a considerable amount of material was moved laterally during major channel shifts. A large part of the material eroded at one loop in the river was probably redeposited as a point bar on the inside of the next loop downstream. An example is shown on plates 22 and 23. Between 1954 and 1988, over 115,000 cy of material was eroded from the right side of the channel and redeposited to the left. However, the net change in volume for the reach was only 8,500 cy. The total accumulated volume of material involved in local erosion and deposition between surveys was probably considerably higher.

Erosion-volume calculations for the period 1954 to 1967 contain an uncertainty related to the construction of the Federal Project levees in the early 1960's. The volume calculations were strictly based on the geometric differences in the riverbed profiles between the levees and did not distinguish between material that was borrowed for levee construction and material that was lost due to erosion. In addition to levee construction gravel has been borrowed from the river channel for use in highway construction and other activities in Area 9 and downstream of the Highway 22 Bridge. A total of 75,000 cy of gravel were removed by the Wyoming Department of Transportation between 1980 and the present. A private company removed additional gravel upstream and downstream of the bridge in the 1970's. In addition to the above uncertainties, in Area 10 there is an uncertainty resulting from an unresolved discrepancy in the recorded coordinates for two or three monuments which mark the end-points of the sediment ranges. If the ranges were surveyed in the wrong location, the volume calculations, for the periods associated with the error, could be affected.

7. SURFACE AND SUBSURFACE INVESTIGATIONS.

In the fall of 1996, an investigation of surface materials was carried out in all four areas. The purpose of the investigation was to provide documentation on the size variation of surface materials; to detect changes in the surface armoring that could be related to sediment supply, hydraulic conditions, or other factors unique to the particular area; to determine sizes needed to provide a measure of channel-bed stability; to determine the vulnerability of the channel bed to erosion, once the gravel bed was removed; and to determine how much oversize material would be encountered during gravel removal operations.

Initially, an effort was made to characterize the bed by systematic pebble counts. In this operation, pebbles were systematically picked up and measured along selected sediment ranges. After measuring several ranges, it was realized that this method was too slow. There was too much variation along a single range for the method to provide useful information. A grid method, with a much higher density of sampling, would have been required to characterize each area.

It was then decided to proceed with the characterization by photographic methods. A 3-foot-square frame was marked with feet and tenths of a foot along each edge. This template was then placed at typical locations along selected cross sections such as channel bottoms, tops of bars, and major changes in surface-grain size. Photographs

were then taken and the location was recorded by pacing, noting physical features, and Geographical Positioning System (GPS) coordinates. Where possible, this data was collected along existing sediment-range lines, with additional points taken to characterize gravel bars, shorelines, or other bed variations between the ranges. Due to time constraints, complete coverage of all areas was not possible.

The document containing the results of the photographic survey was too extensive to include in this report. Typical pages from the report are included on plates 24 through 27. These photographs were taken in Areas 1 and 4. These photos were included for illustration purposes only and should not be used to document surface conditions at any location. Copies of the complete document and maps indicating the location of photographs are retained in the Walla Walla District, U.S. Army Corps of Engineers, and the office of the Teton County Natural Resources District.

In addition to the photographic record, three composited, sub-surface samples were collected from each area. The location of the center of each gravel sampling site is marked on plates 32 through 35. Samples at each site were composited by mixing 1 cy of material from a central pit with a similar volume of material from four additional pits located about 100 feet out from the central pit. Prior to collecting the sample, approximately 1 foot of material was stripped from the sampling area to remove any surface armoring. After mixing material from the five pits, a 1 cy sample of the mixed material was collected and sent to the lab for grain size analysis. A total of 12 samples were collected and analyzed from the four study areas.

In addition to the above samples, data from a 1980 study titled, *Evaluation of Selected Gravel Removal at Nine River Locations in Teton County*, by M. M. Skinner was plotted as a comparison with the recent data.

The subsurface sampling provided data for use in evaluating the maximum depth of erosion that could occur if the armor layer was to be removed over a large area. It also provided data needed to set up a sediment transport model.

The results of the subsurface investigations are summarized on charts 7 through 15. The results from the 1980 study compare closely with recent sampling in Area 9 (see charts 11 and 12). The wider variation among the 1980 samples is probably due to the smaller sample size and variations in the depth of the samples. Note that the grain size of material collected upstream of the County Bridge on the Gros Ventre is smaller than that collected downstream (charts 7 and 8).

As a general observation, there was a very wide variation in surface material sizes at the sampling locations, ranging from medium gravel to large cobbles. Below the surface, however, the material was surprisingly uniform. The variation in surface material was due to the formation of a surface armor layer in both the main channel and in some back channel or overflow areas. The sizes making up the armor layer varied considerably depending on the energy of the flow at a specific location. The largest sizes were found in areas that had been exposed to the concentrated flow of the main

channel. The sizes of the largest elements of the armor layer generally ranged from 4 to 6 inches in middle dimension (or roughly sieve diameter) in areas that had been exposed to the main-channel flow, and where a well-defined armor layer could be directly observed. Very little material exceeded 12 inches in maximum dimension. The surface investigations described above were performed in the fall of 1996. The 1997 runoff season resulted in a peak flow of 32,000 cfs, which exceeded the estimated 100-year average recurrence interval. After this flood, some of the material, observed in the channel bed just upstream of the Jackson-Wilson Bridge, was up to 8 inches in middle diameter. See section 9a for more discussion on gravel stability.

Cobbles 4 inch and larger usually accounted for 5 to 20 percent by weight of the subsurface material. However, one composite sample, located just upstream of the Jackson-Wilson Bridge contained about 27 percent of this size. From visual observations, there appeared to be a small, but noticeable, coarsening of the armor layer in the upstream direction from Area 1 to Area 10.

8. PHOTOGRAPHIC RECORDS OF EROSION AND CHANNEL CHANGES.

In order to document historical channel changes and erosion that have occurred in the past, all of the available aerial photographs of the area, some dating back to 1944, were assembled. In some areas, photos had been taken on 17 different years. These photographs were reproduced at the same scale and overlaid to produce a record of the progressive erosion of vegetated islands and shoreline between 1944 and the present. Changes in the active meander belt were then traced onto a master sheet, transferred to a Computer Aided Design/Drafting (CADD) format and color coded to indicate the year and area of vegetation which was destroyed or severely damaged by erosion. Maps of each area, color coded to indicate the dates and areas of erosion are indicated on plates 28-31. One of the objectives was to determine how much of the floodplain was being reworked, and what areas had been undisturbed during the recorded period. Based on the photographs it was also possible to roughly estimate changes in the active meander belt area and channel length. The analysis provided information on erosional trends, level of instability of each area, characteristic overflow routes, and meander magnitude and length. The quality of the analysis varied somewhat depending on the quality of the photograph and the sharpness of the demarcation between areas of erosion and deposition. In many areas, overflow resulted in only minor damage to the vegetation, in others there was a very sharp line between soil and vegetation which had been totally removed and adjacent areas that had not been disturbed. The results of the photographic analysis are described in greater detail for each of the restoration areas in section 9.

9. CHANNEL RESTORATION MEASURES.

a. General Overview.

Restoration measures consist primarily of construction of brush fences, excess gravel removal, and placement of logs and root balls designed to protect and

re-establish wetland and riparian habitats. The brush fences would be placed at the front and sides of existing wooded islands to protect an existing resource or in areas where riparian vegetation has been lost in an attempt to regain the lost soil and vegetation. Generally, attempts to regain vegetation area has been limited to that which existed prior to 1973 in order to avoid reducing the level of flood protection that existed at that time. The purpose of the fence structures is to block, slow down, or deflect the force of the current during high flow periods in order to protect existing vegetation and allow new vegetation to become established. Fences have been used effectively in low velocity regimens in a number of areas. Their effectiveness in the high-velocity regime that exists in this area remains to be demonstrated.

Gravel and cobbles will probably accumulate to some extent with any reduction in the flow velocity, but flows must be reduced well below 2 fps if a layer of soil is to be re-established. Willows, and other vegetation which grow in the gravel bed will assist in reducing velocities and encouraging the deposition of silt if they can be protected from direct attack long enough to become established. Plate 25, figures 8 and 9 show a natural accumulation of sediment in protected areas of a gravel bar. Plate 26, figures 10, 14, and 17 show overflow areas where velocities have slowed and sediment is accumulating. As vegetation becomes established it further slows flow velocities and encourages accelerated sedimentation. Note how willows and other vegetation are springing up on what was once a cobble bed in plate 26, figure 15.

If a fence fails to perform satisfactorily, it should be possible to add more cross cables or wire mesh to increase the trapping efficiency of the structure. A few seasons of operation may be required to measure the effectiveness of the fences and to adjust the existing fence designs for optimum performance. If the fences operate successfully, debris will be swept by the eddy current into the space between each fence, and a raft of logs, limbs, and other flotsam will collect upstream of the fences and form the matrix through which willows and other vegetation will become established. Sand and gravel will collect in the triangular, protected zone downstream of each fence. As vegetation becomes established it will further resist the flow and encourage the accumulation of a new layer of silt which will support a progressively larger variety of vegetation.

In most cases the fences will have very little effect on the overall river conveyance. They only block out a small portion of the available conveyance and they are generally in locations where conveyance is reduced or the river has ample room to cut a channel around the protected area. At other locations, the fences protect and maintain existing stands of timber that presently block most of the flow through the affected area. Proposed fences which encroach on open areas are nearly always located where heavy stands of mature vegetation and soil once existed and previously blocked most flood flows.

Gravel will need to be removed in some areas. In most of the areas where vegetated islands are to be restored, gravel will need to be removed initially in order to increase the capacity of the stream and offset the loss of conveyance resulting from the

brush fences. The stream would naturally enlarge the channel and regain its conveyance with time, but a flood coming in the season following the completion of the fence might raise the water a small, but unacceptable, amount above the regulatory flood level. In some other areas, gravel accumulation in the active channels may be contributing to the river instability.

Conventional gravel-removal methods would selectively remove the coarse, armor layer on the surface, leaving the underlying material exposed to excessive erosion as a new armor layer is developed. As previously mentioned in section 7, where an armor layer has developed, it generally ranges from 4 to 6 inches in diameter in the main channel areas. Using the Meyer-Peter approach for the beginning of motion (*Sediment Transport Technology*, Simons & Senturk), rough calculations were performed to estimate the sizes that would be stable in the bed. At a 100-year flood level, the average hydraulic radius may vary from 5 to 6 feet and possibly as high as 10 feet at some locations. Using an average slope of 20 feet per mile, a gravel density of 2.95 for basalt, and hydraulic radius values of 5 to 10 feet, the critical diameter for incipient motion ranged from 2.6 to 5.1. Obviously, there are local reaches of the channel that are much steeper, and local turbulence increases the probability that larger sizes will be put into motion. It is not surprising then, that larger sizes were often observed in the channel armor layer.

Although the large gravel sizes form a relatively small fraction of the total material in the channel bed, they contribute significantly to the overall bed stability by providing material from which the armor layer is developed. Bed stability is also enhanced by retaining sizes in the bed that transport at a very low rate even when the critical tractive force is exceeded for that size. In order to minimize channel-bed erosion, gravel 4 inches and larger will be retained and restored to the channel bed. These sizes, generally, constitute from 5 to 20 percent of the mixed gravels in the bed. The selection of a 4 inch minimum size was, to some extent, an arbitrary decision. However, it appears reasonable considering the observed sizes forming the armor layer, logistic limitations involved in processing and returning the material to the channel bed, and the need to retain the largest sizes.

A second function of gravel removal is to reduce the supply of gravel to an area that is overloaded. This, if combined with measures that increase gravel bar stabilization, will result in channel entrenchment and a reduction in the rate and frequency of lateral movement. A third function is to take the pressure off of an eroding bank by opening up existing secondary channels and shifting some of the flow back toward the center of the meander belt. Brush fences and anchored debris are designed to encourage vegetation growth and help to stabilize the channel pattern. The level of success in maintaining an alignment will probably vary widely with the location and degree of bank stabilization accompanying the gravel removal.

The above objectives could be achieved with reasonable confidence in a meandering channel with a low sediment load. However, the Snake River carries a heavy bed load and is very unstable and braided. It is very difficult to determine how

much sediment is being transported, where sediment will be deposited next, or where the channel will be after the next flood. By its very nature, the river is unpredictable and may not respond as desired in some areas.

No attempt has been made in this Appendix to cover all of the environmental considerations that should be addressed. However, changes in sediment transport and river hydraulics, resulting from the implementation of various restoration measures, will have environmental impacts that will need to be considered. In the remainder of the report the term "improved channel" is sometimes used interchangeably with the term "restored channel" to refer to the modified condition after restoration measures have been implemented in an area.

The grain sizes of materials on the surface vary considerably in size from silt in some areas to cobbles 5 to 10 inches in mean diameter. The size depends to a great degree on the velocity of flow at the particular location. However, 1 foot or more below the surface the material is more uniformly distributed with very little silt and generally less than 15 percent larger than 4 inches. When the river is returned to flow over an excavated area there will be an initial increase in turbidity as the flow picks up the fine material from the surface. This should be of very short duration, perhaps a few hours. Later on, as the flow increases during winter floods or the spring runoff period, the bed will be reworked, and one of several processes will dominate. Fine material in the bed will be entrained and put into suspension, then, depending on the sediment supply from upstream, more sediment will be deposited than is entrained; an equilibrium will be established between entrainment and deposition; or, if there is a deficient supply, erosion of the bed will occur until enough large material remains to form a new continuous layer over the bed that will protect the underlaying material from further erosion. Cobbles which form the new armor layer would come from material transported into the site from upstream, oversize material physically returned to the bed during gravel removal operations, and material existing in the bed. In the extreme case, with a deficiency of supply from upstream, and no return of cobbles to the bed, the channel bed could degrade to a depth of 2 to 10 feet depending on the amount of large sized material in the bed. Restoring the +4-inch material will significantly reduce the depth of degradation from an average runoff event, since this material will be redistributed over the surface by the current to form a new armor layer.

In some areas, root wads or logs will be anchored. The root wads are designed to accomplish some of the same objectives as the brush fences. They will have less of a visual impact and should spread the effect over a larger area. In areas of low velocity, sand and silt will collect downstream of the debris and encourage the establishment of vegetation. In higher velocity areas, a sufficient number of root wads will tend to slow the velocity and deflect most of the current around the area to be protected. In some areas, when exposed to the main current the root wads will actually increase erosion by flailing around on the restraints and stirring up the gravel. In these areas holes, several feet in depth, will be eroded in the channel where each root wad is anchored.

b. Design Criteria and Probabilities.

For purposes of comparing the costs and benefits of different levels of protection, it was necessary to select a criteria for design and assign a probability of success to various elements of the design. Since there was virtually no historic data of a type that could be used for a rigorous probability analysis for this type of project, probabilities were primarily based on experience and judgment.

The maximum design life of 50 years seemed to be a reasonable value, since woody vegetation will reach a mature level during that time. It also corresponded roughly to the period of aerial photographic data documenting changes in the channel and surrounding vegetation. During this period, virtually all of the vegetated islands within the meander belt were destroyed at one time or another by the changing channel patterns. In order to provide a comparison, shorter design periods, which actually represent intermediate levels of reliability in the selection of structural elements and restoration measures.

From the frequency curve on chart 3, it can be seen the peak annual discharges for average return intervals of 15, 25, and 50 years are 22,500, 24,000, and 26,500 cfs. Obviously, there is not enough difference in these flows to serve as a criteria for design of structures whose probability of failure is related more to attack by impinging flows, impact by floating debris, and changes in channel alignment, than by a specific flood frequency. For this reason, it was decided that a design based on attack by floating debris under three different impinging flow velocities along with the traditional static hydraulic loading, would be a more reasonable approach. Impinging flow, for purposes of this analysis was defined as flow that had a much greater attack velocity due to a local steepening of the upstream channel. The design impingement velocities were based on expected levels of attack. Velocities of 4 fps or greater could be expected when the structures were exposed to high flows even without impingement conditions. For this reason, structures should not be designed for anything less than 4 fps. Impinging velocities of 8 fps were frequently seen in the data and 12 fps occasionally appeared in the data. These velocities were used as a basis for the development of three separate fence designs. Structures designed for 4 fps would suffer substantial damage if exposed to direct attack by an typical impinging flow. The probability of being exposed to this type of flow may range from 5 to 10 percent each year based on a rough estimate of the length of levee exposed to impinging flows. If 7 percent of the structures were substantially damaged each year, this would roughly correspond to a 15-year life for structures designed for 4 fps. Structures designed for 8 fps would be more likely to survive some impinging attack, perhaps providing a 25-year average life. However, with the present design, the structures would not provide enough continuity to restrict the channel to a fixed alignment. The braided channels will eventually bypass even the strongest structures, attack the vegetated islands from an unprotected angle and eventually render many of the structures useless. It does not seem reasonable, based on the past erosional history of the river, to assign a project life greater than 50 years. Vegetative growth was based on the assumption that over the entire project the average, effective-life of the fences would

correspond to the selected intervals. On an average, substantial reconstruction of the entire project would be required at the indicated intervals.

In some areas, the restoration measures may be very successful, in others there is likely to be extensive failures. By analyzing past erosion trends and channel patterns, an attempt has been made to maximize the probability that most of the measures will be located in areas where they will meet with an acceptable level of success. The paragraphs below describe each study area and along with the proposed restoration measures.

c. History and Proposed Restoration Measures for Area 1.

(1) Description.

Area 1 encompasses a long sweeping bend in the Snake River and its associated overflow channels and wooded riparian zone (see plates 1 and 32). It is located about 3 miles upstream of the Highway 26 Bridge, starting at the confluence of Spring Creek and extending upstream about 2 miles. The Snake River enters the area flowing generally South, then swings nearly 90 degrees to the East as it comes up against the Snake River Range which blocks its southward path along the lower one-third of this area. The river and its adjacent wooded riparian zone spreads out to a width of about 1 mile around the this bend, but narrows to 2,000 feet or less where the braided channels converge at the lower end. The present river generally flows around the outer edge of the riparian zone. During high flow periods, the river overflows into a network of smaller channels that cut across the bend and empty back into the Snake River along the lower half of the bend. During low-flow periods the upper ends of these channels may be dry, but progressing downstream, water seeping in from the shallow aquifer keeps the larger branches flowing during the entire summer.

The channel is highly braided, with 2- to 5-degree braiding over most of its length. The adjacent floodplain is wide and flat. During high-flow periods the channel boundaries are poorly defined and constantly changing. Gravel may completely fill the channel at some locations causing the flow to fan out over a wide area. Close-up views of the channel that indicate the typical variation in surface bed material sizes are shown on plates 25 through 27. (Photo 1 was taken from the top of the levee, looking outside the levee and downstream along a small stream fed by the three culverts shown in photo 2).

A review of historic aerial photographs indicates that the active channel has frequently changed course and pattern. A USGS quad sheet, based on 1927-1931 surveys, indicated that the channel at that time was more centrally located within the meander belt and divided into three main branches. Both of the east branches emptied into Spring Creek that joins the Snake River at the downstream end of the bend. By 1945, it appeared that the central branch of the channel was being abandoned, but a large channel still cut across to Spring Creek. Over the years, the channel moved westward, progressively eroding a 1,000-foot-wide wooded riparian zone and cutting

into developed pasture lands to the west. In the process, it almost completely abandoned the branch into Spring Creek. Sheet flow still covers the interior gravel bars during spring floods, but willows are springing up and sand and silt is building up on large areas that were formerly expanses of bare cobbles.

The date for the most recent westward channel movement is not known. There was some westward erosion evident in 1956. A couple of loops were cut into the zone between 1960 and 1962. Large areas of vegetation were washed away between 1967 and 1971, between 1974 and 1981, in 1986, and between 1992 and 1996.

Near the downstream end of Area 1, a large portion of the Snake River formerly flowed into and along the present course of Spring Creek and then flowed back into the main channel from the left. The momentum of the lateral flow and sediment replenishment from this branch of the Snake River probably tended to keep the channel pushed up against the hills to the south. A groin, located just above the confluence on the left side, can be seen in 1953 aerial photos but appears to be partially or completely destroyed in 1956 photos. Since 1962, the river has progressively cut away slices of the left bank. By 1996, the river had cut nearly 800 feet into riparian land near the mouth of Spring Creek. Plate 28 indicates the chronological sequence of vegetation loss due to erosion between 1945 and 1997.

Several factors suggest that the river is either moving large volumes of gravel with no net loss; or the area is aggrading:

(a) The river banks are poorly defined or nonexistent.

(b) The river is invading new areas beyond the meander belt.

(c) The meander belt is three to four times as wide as the active channel.

(d) During peak flow conditions, flow is often shallow and spread out over mid-channel islands, which appear to occlude most of the channel cross section.

(e) There is an absence of recent terrace formation or other evidence of channel entrenchment.

The low-flow channel exhibited a wide variation of patterns over the years. During some years, such as in 1996, a definite, repeated pattern of fairly uniform meander loops could be seen within the overall braided pattern. In 1945, there was little, if any, regular meandering pattern identifiable within the overall braiding. The 1996 pattern appeared to be more typical of identifiable patterns during the 1945-1997 period.

Listed below are comparisons between conditions in 1945 and the 1996. It should be noted that a peak flow of 22,800 cfs occurred in 1943, while peak flows of

12,000 and 14,100 cfs occurred in 1944 and 1945 respectively. The peak flow in 1996 was 24,800 cfs. The condition of the active meander belt in 1945 may have been strongly influenced by the high flow that occurred 2 years earlier.

(2) Hydraulic and Geomorphic Parameters.

Year of Aerial Photograph	1945	1996
Length of Low-Flow Channel:	8,800 feet	9,550 feet
Cannel Slope:	15.6 feet/mile	14.4 feet/mile
Meander Length:	3,400-3,800 feet	2,600-3,000 feet
Active Meander Belt Length:	8,100 feet	8,700 feet
Average Slope:	17 feet/mile	16 feet/mile
Active Area:	210 acres	223 acres
Width:	1,130 feet	1,120 feet

In the above list, the active meander belt was defined as the area recently disturbed by the river, based on visual examination of aerial photographs. Disturbance was determined by obvious damage or loss of vegetation by erosion. Water surface elevations were obtained from 1996 surveys.

(3) Restoration Measures.

(a) Channel Alignment.

The natural channel pattern will be retained and allowed to develop to the extent possible. However, several existing channels would be enlarged, as indicated on plate 32, to shift some of the flow back toward the center of the meander belt, take some of the erosive pressure off of the right bank, and allow re-establishment of a riparian zone in this area.

(b) Removal of Excess Gravel.

A gravel-removal zone, designed to match a typical second-degree braiding pattern, was selected at the upstream end of Area 1. Removal of excess gravel at this location would reduce the supply downstream, encouraging moderate entrenchment of the downstream channels and reducing the frequency and extent of lateral movement. Cobbles over 4 inches in mean diameter would be retained to form an armor layer on the bed and banks of the channel.

The site was chosen for the following reasons:

1. The location allows easy access along the west side from the Taylor Creek levees or the nearby county road.

2. The location would reduce the supply of gravel entering the site while minimizing the area that would be disturbed when excavation was in progress.

During hydraulic modeling of the above channel modifications it was found that the brush fences resulted in a calculated rise in the water level upstream. To offset the effect of the fences, additional excavation was proposed along several existing, secondary channel alignments as indicated on plate 32. This excavation should take some pressure off of the right bank by shifting a majority of the flow back toward the center of the meander belt. The channel modifications will shorten the effective length of the channel and increase the channel conveyance. The upstream sediment trap will reduce the sediment supply. If successful, these modifications should maintain adequate conveyance through this reach in the future with little or no maintenance. After completion of the project, the area should be monitored by periodic resurveys of sediment ranges to assure that the amount of sediment removed from the sediment trap does not result in excessive channel entrenchment downstream.

(c) Pool and Channel Restoration.

Two existing channels were identified and selected for restoration measures. Four pool sites were selected along these channels. The selected sites provide varying degrees of exposure to erosion and sediment inflow. The two pools farthest from the main channel will collect finer sediment and should survive the longest. Connecting channels and associated pools will create flow and depth diversity, root balls, and other in-water debris will provide shade and shelter for fish and other aquatic life.

(d) Debris Fences.

Debris fences and root-ball fields along the west bank of the channel are designed to collect sediment, encourage woody vegetation growth. The objective is to stop the westward channel movement and recover most of the riparian habitat lost since 1973. The proposed locations for the brush fences cover areas formerly occupied by mature riparian vegetation, which has been destroyed since 1973. See plate 32. Debris fences on the left side of the channel are designed to protect large stands of mature cottonwoods should the river shift back eastward across the meander belt. As experience is gained, it may be necessary to make some adjustments or modifications to the fences in order to improve their debris-trapping efficiency or to control erosive velocities between the fences. The modifications might consist of the addition of fence spurs connected to the existing fences or the placement of additional fences or fence panels between the existing fences.

d. History and Proposed Restoration Measures for Area 4.

(1) Description.

Area 4 covers a braided reach of the river starting at the downstream end of the Federal Levee Project and extending downstream a distance of 1.6 miles (see plate 1). Three small tributaries called Fish Creek, Mosquito Creek, and Cottonwood Creek enter the Snake River from the right. The Upper Imenson levee forms a boundary to the left. Prior to construction of the Federal Levee Project the river often followed an alternate course well to the right of the existing levees, with a significant flow following the present course of Fish Creek. During high flow periods some of the flow escaped into "spring creeks" which branched off of the main channel in the riparian zone to the left. Levees and levee extensions now cut off most of the overflow into these channels. A photographic overview of Area 4 is shown on plate 24. Typical close-up view showing armor layer material and the variation in surface bed material sizes is shown on plate 28.

Historic aerial photographs indicate that the river was rather unstable in this area. Flows followed alternate paths through the area, sometimes spreading out over a fairly wide area, and at other times cutting a single narrow channel through the reach. A characteristic, low-flow meander pattern did not appear to be present in this area. The active meander belt has experienced considerable lateral expansion between 1954 and the present. Large areas were eroded in 1973, and again in the 1986 to 1997 period (see plate 29). Between 1945 and 1954 the active, vegetation free zone of the channel occupied and average width of about 1000 feet. In 1977 flood waters spread out to a width of 2,400 feet with very little vegetation left in between. The location and method used in previous cross section surveys do not provide a sufficiently accurate basis for analyzing gravel erosion or deposition in this area. However, several factors strongly suggest that gravel is building up in this area:

(a) The levees immediately upstream of the study area have severely restricted the opportunity for flood flows to spread out and flow into alternate channels. Gravel transport and deposition is now restricted the area between the levees.

(b) Repeated resurveys of monumented sediment ranges in the upstream Federal Levee reach indicate a net loss of gravel between the levees.

(c) Termination of the right-bank levees theoretically provides an opportunity for transported gravels to drop out as the flow spreads out over the unrestricted floodplain.

(d) The evidence of progressive widening of the meander belt is consistent with the expected response of the meander belt to excessive gravel deposition in this area.

(2) Geomorphic Parameters.

	1945	1996
Average channel slope:	18.75 feet/mile	8.4 feet/mile
Average width excluding islands:	875 feet	1434 feet
Average total width of active		
Meander belt:	998 feet	1570 feet

(3) Restoration Measures.

(a) Channel Alignment.

The channel at this site has been extremely unstable over the last 50 years, with no identifiable, characteristic, low-flow channel pattern. The indicated pattern utilizes an average meander length observed at other sites within the overall study reach, and represents a pattern that the channel may naturally assume after implementation of restoration measures. If the channel has shifted to the far right or left side of the meander belt prior to project implementation, some excavation may be required along the indicated channel alignment in order to shift the low-flow channel back to the center of the meander belt. This should be a one-time operation. Gravel excavation sites and other restoration measures are indicated on plate 33.

(b) Removal of Excess Gravel.

The supply of gravel entering this site from upstream will be reduced in order to increase channel stability. Two areas were designated for gravel removal. The size of these sites has no bearing on the amount of gravel to be removed. The maximum area of disturbance during any year would be less than one-half of the delineated areas.

The sites were chosen for the following reasons:

1. The location provides easy access for equipment using levee-access roads along both sides of the river.

2. The shape and size of these sites match active gravel-exchange areas at these locations, as observed in the 1996 aerial photos. The shape of the upper site was modified to allow room for partial recovery of vegetation and soil lost on a nearby wooded island since 1973.

3. Location of the gravel sites along the left bank provides a high degree of assurance that gravel will be intercepted before it enters the area of greatest instability. Large cobbles will be retained during gravel removal and will be used to armor the upstream and downstream ends of the pools.

(c) Pool and Channel Restoration.

In addition to the gravel sites, three smaller sites were selected off of the main channel where they would be fed by spring creeks or secondary channels, and where they would be protected to some degree from direct erosive attack during flood flows. The small channels feeding and draining the two larger pools will provide opportunities for fish-habitat improvement.

(d) Debris Fences.

Debris fences would be used to protect several existing islands supporting mature woody vegetation. The fences will be designed to collect debris; and to slow and deflect the flow during average spring runoff periods, but they will be over-topped during extreme floods.

(e) Spur Dikes.

Groups of spur dikes would be located at two points along the levees. These dikes would provide velocity-diversity and resting areas for fish. Properly spaced, they could provide a secondary benefit by providing increased erosion protection for a short reach of the levee.

e. History and Proposed Restoration Measures for Area 9.

(1) Description.

Area 9 covers a 1-mile reach of the Snake River in the vicinity of the Jackson-Wilson Bridge (see plate 1). The downstream limit is just below the Jackson-Wilson Bridge. The upstream limit is about 700 feet upstream of the Prosperity Ditch intake. The earliest available map for this area is a 1946 USGS Quad sheet that was a reprint of a 1901 map based on 1899 topographical surveys. This map indicated that the channel was braided in at that time. Within the study reach, the lower two-thirds of the channel was divided into two main channels that extended downstream through the Jackson-Wilson Bridge. Later maps and aerial photos showed a similar pattern. Rock-filled timber-cribs were used to construct bridge approach walls, four large groins on the left bank, and an isolated section of levee at the Prosperity Ditch inlet. These structures were included in 1938 maps of the area. Several of the groins can still be seen along the left bank upstream of the bridge.

The bridge forms a rather severe constriction in the active meander belt. During the early and middle 1950's the active channel widened considerably just upstream of the bridge. This may have been a response to unusually high flows and associated gravel deposition upstream of the bridge. Levee construction immediately upstream of Area 9 probably resulted in additional transport into this reach. The area of exposed gravel increased by 28 percent between 1944 and 1953, leaving only 15 percent of the meander belt in vegetated islands. Construction of the levees through

this area in the late 1950's and early 1960's narrowed the active meander belt, funneled flows through the bridge, and probably increased the efficiency of gravel transport through this area. In 1996, there was actually more vegetative cover than in the 1950's and early 1970's. Aerial photographs indicate rather extensive gravel removal below the bridge along the left bank and at the upstream end of the study reach in the 1960's and early 1970's. Part of the work was for levee construction The photographic history of channel change and island erosion is indicated on plate 30.

(2) Geomorphic Parameters.

	1944	1996
Length of low-flow channel:	5,810 feet	5,635 feet
High-flow channel:	5,520 feet	5,310 feet
Active meander belt:	5,140 feet	4,990 feet
Valley width:	4,990 feet	4,990 feet

Slopes (feet/mile) based on surveyed water surface:

Ranges	5-1	5-4	4-1
Low Flow Channel:	18.3	21.6	14.8
During High Flow:	20.1	26.9	14.6
Meander Belt:	20.9		

Meander belt and channel widths.

	1944	1996
Active channel:	934 feet	780 feet
Total Average Meander Belt:	1,350 feet	1,100 feet

(3) Restoration Measures.

(a) Channel Alignment.

The alignment for channels in this area follows a typical alternating pattern that has existed since about 1960. By encouraging the river to follow one or both of the selected channels some vegetation growth should be possible in areas which were frequently destroyed by the shifting channel. Some excavation will be needed, at least initially, to stabilize the channel until vegetation can become established. Plate 34 indicates selected channel alignments and other restoration measures.

(b) Gravel Removal.

Some gravel removal will be required to keep the selected channels open, and to provide additional flow area to offset flow resistance caused by new vegetation growth. If restoration measures are effective, only limited gravel reshaping or removal may be needed in the future. Cobble-sized material will be returned to the bed and to the upstream ends of islands to retard erosion.

(c) Pool and Channel Restoration.

Several pools sites were selected in the protected area near the left bank levee. Sites were selected where direct exposure to the main current would be minimized. Small secondary channels connecting these pools should provide opportunities for fish habitat improvement.

(d) Debris Fences.

Debris fences are designed to reduce velocities and collect sediment, allowing the soil to rebuild and vegetation to extend out from the remnants of a wooded island. Cobble armor and anchored root balls will be used to break the force of the current and allow vegetation to become re-established on islands between the selected channels. Abandoned bridge piers will serve as anchors for some of the fencing.

(e) Spur Dikes.

Groups of spur dikes would be located at three points along the levees where flow impingement or long reaches of sustained, high-velocity flow is expected. These dikes would provide velocity diversity and resting areas for fish. They would also strengthening and increase the effectiveness of the adjacent levees.

(f) Bed Stabilization.

A bed of rock is shown connecting the left bank levee with the debris fences. This material is designed to allow passage of flood flows while preventing the establishment of a permanent channel through the protected area along the left-bank levee.

f. History and Restoration Measures for Area 10.

(1) Description.

Area 10 covers a 2-mile reach of the Snake River at the Gros Ventre River confluence (see plate 1). The Snake River runs south, directly into Gros Ventre Butte, then turns west in the lower half of the study reach. The earliest available map for this area is a 1946 USGS Quad Sheet, which was listed as a reprint of a 1901 map with some roads and other development, added. The map topography was surveyed in 1899. This map depicted a braided channel pattern with up to three main branches. The Gros Ventre appeared to enter the Snake River over 1,000 feet upstream of its present confluence. A 1938 map indicated a similar degree of braiding with a somewhat different channel pattern. A 1944 aerial photograph shows the Gros Ventre channel split as it approaches the confluence with part of the flow following the old channel route and the other part entering at the present confluence location.

Aerial photos from the early 1950's indicate that the river was highly unstable with large areas of exposed gravel upstream of the Gros Ventre River and near the downstream end of the study area. However, downstream of the confluence for about one-half mile the channel was surprising stable with vegetation growing relatively close to the active channel banks. By 1960, levees had been constructed along the left side of the active meander belt. The levees followed a secondary channel, enclosing a 60-acre wooded island at the confluence. Since construction of the levees, there has been a moderate expansion of the active meander belt into the wooded riparian zone to the East. The Snake River progressively eroded the confluence island from both sides. By 1996, more than half of the island had been washed away. Additional erosion occurred in 1997. With a new channel cutting through the center of the island, the remaining trees will probably wash away within a few years. The history of channel changes and island erosion, based on historical aerial photos, is shown on plate 31.

(2) Geomorphic Parameters.

	1944	**1996**
Length of Low-flow channel:	11,440 feet	10,600 feet
High-flow channel:	10,900 feet	9,650 feet
Meander Belt:	8,980 feet	8,980 feet

Slopes based on surveyed water surface:

	1944	**1996**
Low Flow Channel:	17.4 feet/mile	19.8 feet/mile
During High Flow:	19.1 feet/mile	23.0 feet/mile
Meander Belt:	25.7 feet/mile	25.7 feet/mile

Channel and Meander Belt Widths

	1944	**1996**
*Average Active Meander Belt:	885	1,433

**Total Width Above Gros Ventre:	1,663 feet	2,063 feet
Below Gros Ventre:	1,564 feet	1,550 feet

*Average Active Meander Belt width was determined by visually examining aerial photographs and measuring the vegetation free area and lightly vegetated areas obviously exposed to recent severe erosive forces. This area was divided by the length of the channel-centerline to determine the average width of the area occupied by the river during high flows.

**The total width of the active meander belt is the average width of the active meander belt including mid-channel islands that do not contribute significantly to the river conveyance.

(3) Restoration Measures for Site 10.

(a) Channel Alignment.

Although the channel is highly braided, the main channel has usually followed one or more of several identifiable courses through the area. Gravel excavation, debris fences, and a pilot channel are designed to shift the main channel activity back into these existing courses. This will take the pressure off of eroding wooded islands to the west and riparian growth along the east bank. It will also shift the channel back toward the center of the meander belt.

(b) Removal of Excess Gravel.

Two sites were chosen for gravel removal. The upper site captures gravel before it enters the restoration site; it directs flow down through the center of the braided area in two distinct channels. It is designed to encourage moderate channel entrenchment and increased stability of downstream channels. It should reduce pressure on eastward lands and to allow vegetation to become re-established on interior islands. The lower site reduces gravel inflow from the Gros Ventre River. It also should take some pressure off of the brush fences and the wooded island to the west by drawing the main current toward the center of the excavated area. Gravel removal will need to be monitored and then adjusted or terminated depending on the observed channel response.

(c) Debris Fences.

Debris fences shown near the top of plate 35 would be used to protect Bear Island and reduce flow into the eastward channel. Other fences near the center of the drawing would be used to restrict flow into the channel along the west levee alignment and encourage eastward accretion of the adjacent, wooded islands. The pilot channel (running through Range 28) will be required to take pressure off of the downstream wooded island area and shift flow back to the center of the meander belt.

(d) Pool and Channel Restoration.

Restriction of flow along the west levee should encourage re-vegetation of this corridor and provide opportunities for aquatic habitat enhancement in the small secondary channel that remains. Two pools would be developed in this sheltered area with root balls, and other woody debris added to provide shade and shelter.

(e) Spur Dikes.

Groups of spur dikes would be located at three points along the levees where sustained high velocities are expected. These dikes would provide

velocity diversity and resting areas for fish. They would also strengthen and increase the effectiveness of the adjacent levees.

10. <u>EXPECTED FUTURE CONDITIONS WITH NO RESTORATION MEASURES</u>.

Future conditions in the four selected areas can only be discussed in general terms. If no restoration measures are instituted, the channel will continue to shift back and forth between the levees in a random manner. Eventually all of the remaining mid-channel stands of mature trees will be washed away in Areas 9 and 10. Since the river does not occupy the entire area between the levees, there will be some recovery, particularly in the wider portions of the channel. Some damaged areas of the channel have recovered long enough to develop a 10- to 20-year growth in the past. However, it does not appear that the river is stable enough to allow any significant areas to remain undisturbed long enough for a 50-year growth to develop. The leveed reach has experienced a net loss of material. However, the rate of loss appears to be decreasing with time. Erosion, and reworking of the channel-bed gravels will continue in the future, but at a gradually decreasing rate. The continual reworking of the channel-bed gravels will result in a progressive loss of fine material that supports vegetation. Recovery of damaged areas will be slower, and larger areas of the channel bed will remain relatively vegetation free.

Areas 1 and 4 are likely to retain a more natural, random distribution of vegetation than Areas 9 and 10, since there is more space for lateral channel movement. Gravel transport and deposition in Areas 1 and 4 was probably the highest just after completion of the levees, and has decreased (on the average) since then. The major flood of 1997 would be a notable exception. For this reason, it is likely that most of the additional damage, resulting from excess gravel inflow, has already occurred. It is not likely that the gross area of denuded gravel beds will increase. However, the continued inflow and deposition of gravel is likely to keep the channel unstable. The channel is likely to continue shifting to one side or the other, attacking new, undisturbed bank-lines on the margins of the meander belt.

11. <u>UNCERTAINTIES, POSSIBLE FAILURES, FUTURE MAINTENANCE, AND MONITORING REQUIREMENTS</u>.

Due to the braided nature of the river, associated uncertainties related to bed load transport, and channel instability, it is not possible, for a reasonable cost, to construct a project that will perform satisfactorily without future maintenance and corrective adjustments. Considering the level of engineering judgement and uncertainty involved in assigning damage levels for different events, further attempts at refinement would probably be unwarranted. The design of individual structures and the overall restoration scheme was based on the acceptance of partial failure of portions of individual structures and the probability of occasional, complete loss of protected vegetated islands leading to a distribution of vegetation of different levels of maturity within the four sites selected for restoration. The maximum velocities of up to 16 fps were measured at very localized, levee-impingement points where flow cut sharply

across the channel following a short drop with a slope of up to 4 times the average slope of the river. Local attacks of this nature are expected to result in localized failures that will be handled under project maintenance agreements.

An attempt has been made in the paragraphs below to describe possible failure scenarios and to suggest corrective measures.

a. Fences.

(1) Possible Problems.

Fence structures of various designs have been tested for use as bank protection or river training structures. A number of these designs and case histories are described in the December 1981 U.S. Army Corps of Engineers Publication: *Final Report to Congress: The Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, Public Law 93-251*. In some cases, particularly in meandering streams where the flow velocities were low, they have proved effective in collecting sediment and stabilizing the channel. The effectiveness of fences in braided channels with high-velocity flow is much less certain.

The effectiveness of the fences will depend, to a large degree, on the amount of floating debris available in the river and actually trapped against the fences. In order to be effective, the fences must trap enough debris to uniformly block most of the flow along the length of the fence. If too little accumulates, the current may pass through the fence with little or no velocity attenuation. An upstream fence may trap most of the available debris, reducing the supply to downstream fences. Depending on the angle of attack, floating debris may be deflected and fail to become trapped against the fences. There is also a risk that excessive flow may escape under floating debris, or erode a path under the fence below the lowest cross cables. Failure of some fence projects in other locations has resulted from insufficient depth of supporting posts, breakage, or an alignment that allowed the flow to bypass or flow behind the fence. At impingement points, velocities of 12 fps (or even higher) have been measured during peak flows. The end of the fence extending out into the channel will be exposed to the greatest stress. There will be erosion around the toe, force fluctuations resulting from debris striking the fence or shifting position, and vibration caused by vortex shedding. In the most severe case, erosion may extend to a depth of up to 15 feet below the water surface. Debris may not collect effectively at the end of the fence leaving the fence exposed at this location. Since undercutting is likely to be the worst at the end of the fence, experience may dictate the need to extend cross cables and wire mesh to a greater depth at this location.

The need for a minimal level of maintenance cannot be overemphasized. The visual impact of the fences could become a major consideration. The fences will create a scalloped pattern of vegetation and debris, with the tips of the fences forming the points. Insufficient debris may leave the tip of the fence or other portions of the structure exposed. With no maintenance, a failed fence could become

an eyesore and a possible hazard with partially-buried woody debris mixed with a tangle of steel posts and cables strung out downstream of the original construction site.

The number and extent of river training structures is not sufficient to assure that the river cannot escape and follow an undesirable alignment. The river will change course frequently and may, for a time, completely abandon the groins, fences, and other restoration features.

(2) Maintenance Requirements.

Where the flow has eroded a channel under the fence the corrective measure would be to add additional cables below the existing ones and attach welded wire fabric panels across the eroded area. This would be done during the lowest flow period of the year, and would likely require men and equipment to work for a few hours in the water. This would also be a good time to locate areas of the fence that are not trapping debris efficiently. Adding a finer mesh that will capture smaller debris can increase trap efficiency, or dragging some of the debris over to places where it is deficient may cover exposed areas. If debris is failing to be trapped or is being deflected around the fence, it may be necessary to add one or more fence panels oriented upstream near the end of each fence, and future fences should be placed at a greater angle upstream. This type of repair will be more extensive during the first few years of operation for two reasons: (1) Experience will be gained as damage occurs and preventive maintenance will be performed at other locations before the damage occurs; and (2) Reinforced areas will be less likely to require maintenance in the future.

Maintenance for posts and fencing that has failed would involve bringing the fencing back in place, installing longer posts, and re-attaching the cables and panels. In some cases it might be sufficient to drive and attach additional supporting posts in locations where the fence is beginning to sag or fail.

Channel abandonment of a protected area will not necessarily represent a failure of the project unless the new channel results in an alignment that threatens or destroys valuable habitat. In some areas adjustments in the location or angle of brush fences will probably be needed in order to continue to provide the design levels of vegetation and habitat under a constantly changing river alignment.

Success of the fences will be measured by the quantity of sediment that collects in front of and behind each fence and the quality and area of vegetative growth that develops in the protected zones upstream and downstream of each fence. Fences, which have been exposed to the flow, should be visually inspected for damage or erosion each year after the high-runoff period. A fence is failing to perform hydraulically if insufficient debris has collected on the fence and high velocity flow continues to pass through the fence, if the channel cuts under or around the land-ward end of the fence, or if the eddy current between the fences is too high to allow sediment to collect and vegetation to become established between the fences. Photographs should be taken at the end of construction to serve as a basis for future comparison of

vegetative growth and sedimentation. Aerial photographs, if available, could be used to directly measure vegetative regeneration.

(3) Demonstration Project Performance

A demonstration project, sponsored by Teton County at Area 9, has provided some late information that was not available at the time this report was being prepared. Although time and funding for this study do not permit an extensive description of the project or a complete analysis of the results, some observations should be considered when preparing for project construction.

Five fences were constructed at approximately the same locations as the five downstream fences shown on plate 34. During the spring of 1999, the fences were exposed to a 10-year flood event that produced observed surface velocities at the end of the fence of up to 10 fps. It was noted that the fences trapped debris much better in areas that were covered with 6- by 6-inch mesh cattle panels than in areas where fencing consisted only of cables spaced 1 foot apart. The fine mesh trapped small debris and backed up the flow effectively. In some locations, up to 18 inches of silt and sand was deposited between the fences. Three posts at the end of two of the fences were damaged. They were gradually bent over as the flow increased and gravel eroded away around the base. Failure occurred at about the 14-foot point on the 20-foot-long posts. A tree that lodged against the last post and extended perhaps 30 to 40 feet out into the main current increased the bending force. As the flow receded below the lowest cable on the fence, a vertical bank line developed near the end of the fence and progressed back some distance under the fence. Large trees tended to cantilever over the eroded area and were not effective in retarding the flow until the erosion had progressed back far enough to allow them to fall into the void. Results from this event suggest that erosion around the base of the outermost posts may be the most critical condition leading to partial failure of a fence.

The above experience generally fell within the estimated damage and maintenance allowances for this project. However, it suggests that the design could be improved and should be reviewed again before final specifications are developed to assess the value of installing brace piling or otherwise strengthening the end post to provide greater resistance to the observed bending forces at this point. Based on the above experience, it appears that the efficiency of the fencing could be improved by covering the entire fence with 6- by 6-inch mesh welded-wire cattle panels. A greater depth of the mesh and additional erosion protection around the end posts might be considered.

b. Secondary or Supply Channels.

It should be assumed that most of the small secondary channels leading to off-channel pools will be blocked by gravel at their upper ends after each runoff season. Although ground water seepage may provide adequate inflow for many of the channels, it may be necessary to re-open some channels in order to provide an optimum

exchange of water for the downstream pools. Starting at the edge of the main channel, a small connecting channel would be extended downstream or the existing channel would be deepened until a flow of 2 to 3 cfs was developed in the channel leading to the pool. In some areas sufficient flow may be developed from ground water seepage without actually having to connect the channel to the main river. The channel-excavation would typically be around 4 feet wide at the bottom, 200 feet long, and 3 feet deep. A backhoe would typically be used to excavate the channels. Where possible, particularly in vegetated areas, it would be desirable to remove the excavated gravel. However, in may cases the amount of material would be small or the location inaccessible, and less disturbance would be involved if it was side-cast and graded to blend with the surrounding terrain.

The secondary, supply channels will have little effect on the overall hydraulics of the system. Hydraulically, these channels will be successful if they survive through successive high-flow periods without excessive maintenance. However, the channels will not be useful if the substrate and flow-regime does not contribute to improved habitat.

c. Sediment Traps.

(1) Possible Problems.

Since the supply of sediment being transported downstream is not precisely known and may vary by at least an order of magnitude during different years, the optimum size and effectiveness of the sediment traps is not known. Gravel removal will need to be closely controlled and its effects monitored. Removal of more gravel than is being re-supplied will result in progressive lowering of the channel bed within the designated sediment trap boundaries, excessive headcutting upstream, and excessive channel entrenchment downstream. This could lead to a local depression of the water table, and undercutting of the toe of the riprap on nearby levees.

During the coldest winter months of November-February, the potential for ice blockage of the active, low-flow channel will be increased in vicinity of the gravel trapping areas. The low-flow channel may be frozen clear across at times with part of the flow passing under the ice cover and the remaining flow backing up and overflowing into secondary channels that would normally be dry at this time of the year. Since the distance between the levees is several times the width of the low flow channel, and there is no development immediately adjacent to the low flow channel in other areas, this condition is not expected to create any increased risk of flooding or other serious problems.

(2) Maintenance.

Areas designated for sediment trapping exist at Areas 1, 4, and 10. Area 9 includes designated alternate channels that will act as sediment traps to some extent. The areas designated as sediment traps should be re-excavated when one-half or more of the initially existing volume is refilled. Typically only about one-half of each

designated area will need to be disturbed during a operation to remove an adequate quantity of gravel. The traps should be excavated to a fixed template that is 2 feet below the excavation level shown on the hydraulic modeling cross sections. See section 13.b. Maintenance operations should only remove excess sediment that has been deposited within the original design boundaries and bottom profile of the sediment traps. Adjustments in the design depth of the sediment traps should only be made in consultation with a qualified engineer familiar with the channel hydraulics and goals of the restoration project. Excavation can be accomplished most efficiently during the low flow months (August-April). However, requirements of the Biological Assessment (BA) may place additional restrictions on excavation methods and timing.

Calculations for Area 1 assumed complete excavation of all designated areas at the time of construction. Future excavation will be required in the upstream site to maintain its function as a sediment trap.

The frequency of refill and the volume that will need to be removed are not known at this time. Sediment transport calculations suggest that more than 400,000 cy of sediment could be transported through the system each year. However, only a fraction of this will be trapped. The volume cannot be predicted with any precision, since the flow area is not confined, and the geometry of the natural river channels is not constant or predictable. Until additional experience is gained, it should be assumed that a high flow, such as a 10-year flood, could fill the traps completely in a single flood event. During periods when flows for successive years are near average, it will probably take several years to fill the traps. Several years of operation will probably be needed to determine the optimum level of gravel removal required to maintain a stable, equilibrium condition.

(3) <u>Monitoring</u>.

Monitoring of the sediment traps will be a critical element of the project during the first 10 years or more after completion of the project. Records should be kept of the amount of gravel annually removed from each trapping area. Sediment ranges should be established and surveyed at the completion of the project. It is recommended that ranges are established at 500-foot intervals through each designated trapping area, extending upstream and downstream a distance of at least 1000 feet beyond the upstream and downstream area limits. The ranges should be re-surveyed at scheduled intervals, or if there is any indication of excessive channel headcutting or downstream degradation. A suggested interval would be 5 years after completion of the project and at 10-year intervals thereafter unless changing conditions indicate the need for a more frequent interval. After each re-survey, the ranges should be over-plotted with the previous surveys and the cross section areas should be compared. This information will provide the means for detecting a net loss or gain of material, and would indicate whether the upstream and downstream channel thalwegs are aggrading or degrading.

A moderate channel entrenchment averaging around 5 feet would be desirable, from a hydraulic perspective, in Areas 1 and 4; while in Areas 9 and 10 maintenance adjustments should be adjusted as required to maintain a stable condition with regard to sediment transport and channel capacity. If aggradation continues in these areas, based on comparison of the surveys, then the design-depth of the sediment traps should be increased and more material should be removed annually until material-volume stability is achieved. A permitting process should be established to assure that the amount of material removed from the sediment traps does not result in a progressive net loss of material from any area.

d. Spur Dikes.

Spur dikes will occasionally be damaged by high flows. Measurements at various locations on the existing channel indicate that erosion can extend down to at least 15 feet below the high-water level. It would not be practical to construct the dikes with large enough stone and with a deep enough toe to avoid any possibility of damage. The mode of damage will likely be undercutting of the toe of the dike and collapse of material into the void with some material being transported downstream. Repair would involve adding enough riprap to restore the original geometry.

e. Off-Channel Pools.

(1) Possible Problems.

Depending on the location and the timing of high flows, pools could be refilled with gravel and cobbles and totally eliminated before they have existed long enough to perform a useful role. In the worst case, some of the pools may be eliminated by the next high flow after construction. Pools in most areas will be subject to refilling during high flow seasons. If this process occurs over a period of time it can actually be beneficial, since it will provide a controlled sequence of differing plant communities and provide more diverse habitat. In some locations, such as Area 1, the pools may serve a dual role as habitat providers and sediment traps. Those located some distance from the main channel will likely last a number of years. They will gradually refill with silt and sand brought in by the interconnecting channels and by general over bank flow during high flow periods. Due to the braided nature of the river, it is nearly impossible to select locations where pools would be subjected to a predictable level of protection from flood events. An additional potential problem is isolation of the pool and entrapment of fish during low-flow periods due to excessive seepage into the gravel bed or banks of the pool. Freezing of the pools and secondary channels during the winter may also be a consideration.

(2) Maintenance Requirements.

Pools near the margins of the active meander belt should be allowed to fill completely, then a new pool should be constructed nearby with a new water supply without disturbing the old pool or its water supply. Where possible, the new pools

should be built either upstream or downstream of the existing pools in order to utilize the same supply channels. Pools constructed near the main channel in the vegetation-free areas of the channel should be re-excavated only when completely filled with gravel. The large, branched pool in Area 1 and a pool in Area 9 meet this criteria. The pool at Area 1 is large enough to influence the gravel exchange in that area and will serve a secondary function as a sediment trap. These latter pools are likely to be progressively filled in during low-flow years. They could be filled in completely during a major event, which could also involve major changes in the main channel. The main channel may even cut a course through the center of a pool. In the latter case the pool would be re-excavated at another location (probably along the previously abandoned channel). The objective would be to maintain approximately the same area of pools throughout the life of the project either by re-excavation at the same location or relocation of a pool to a more advantageous site. This process will result in more diverse riparian communities that are more endemic of the river. Based on biological monitoring results, it may be necessary to adjust the inflow and outflow to provide optimum habitat. Hand-placing or removing woody debris or rock in the entrance or exit channels could make minor adjustments.

(3) Monitoring Requirements.

Visual inspection of each pool in the fall of the year by a qualified individual, and the maintenance of a photographic record, with photos taken at the same location and direction during each inspection, should provide an adequate data base for hydraulic evaluation. Since one of the primary functions of the pools is to improve fish habitat, the pools should be periodically inspected by a qualified fish biologist to determine whether inflows, outflows and conditions during the winter freeze-up period are providing optimum fish habitat. This level of monitoring should be sufficient to document to what extent sediment has refilled the pool and to what extent the hydraulic function and environmental values have changed since the last inspection.

12. OPPORTUNITIES FOR FLOW REGULATION USING JACKSON LAKE.

a. Regulation of Peak Flows and Summer Releases.

Jackson Lake, at the upstream end of Jackson Hole, is an example of a natural lake formed by the terminal moraines of ancient glaciers. At 20 miles long and over 400 feet deep, it provides a major storage and sediment retention reservoir on the Snake River. Most of the 400-foot depth, however, represents the depth of the natural lake. Only the top 39 feet is available for active storage. In 1907, a timber crib dam was completed at the natural outlet to provide 200,000 acre feet of storage for irrigation. This dam washed out in 1910, and was replaced by a permanent earth dam with concrete outlet works in 1911. In 1917, the dam was reconstructed to its present height and storage capacity. The project provided an active storage capacity of 847,000 acre feet at maximum pool elevation (6,769 feet). The minimum pool elevation is 6,730 feet. Seismic stability concerns led to the recent rehabilitation and reconstruction of the project (completed in 1988). Although the maximum pool elevation reduced for a few

years prior to and during construction, provisions for flood control remained unchanged. The Bureau of Reclamation manages current project operation and the associated irrigation contracts.

Between 1917 and 1956, Jackson Lake was regulated primarily in the interest of irrigation storage, with only incidental flood control benefits. These operational policies resulted in an average reduction in the annual unregulated peak discharges of about 4,600 cfs. Since the reservoir was occasionally refilled prior to the occurrence of the actual flood peak, in some years no significant control was achieved. During some low water years, the high summer irrigation releases exceeded the natural peak inflow. In addition, sustained high flows at or near bankfull were blamed for increased bank erosion in unleveed reaches.

In the 1940's, local interests began pressing for changes in the operation of Jackson Lake Dam that would address the problem of local bank erosion. With the construction of Palisades Dam, up to 350,000 acre feet of flood control space (25 percent of the total 1,400,000 acre feet available in Palisades Reservoir) was made available for use in Jackson Lake operational plans.

The formal implementation of this provision went into effect in 1956 when the Palisades Water Control Manual was published. The primary objective of the provision was to limit flows to a maximum of 20,000 cfs below Palisades Dam while providing significant but less reliable control upstream. Typically, the Bureau of Reclamation evacuates a minimum of 200,000 acre feet of space from Jackson Lake with releases that may be higher than inflow during the irrigation season. Additional space can be evacuated depending on runoff forecasts prior to 1 May. If the reservoir has been drawn down below the minimum flood control space on October 1, this deficit may be recovered by gradually refilling during the winter. An attempt is made to limit releases to the 5,000 to 7,000 cfs range during the peak runoff period, although these may be reduced as necessary in an attempt to limit peak flows at the Flat Creek gage to 20,000 cfs. During the period 1956 to 1986, Jackson Lake regulation achieved an average reduction in the annual peak flow at the Wilson gage of 6,200 cfs, compared to 4,600 cfs prior to 1956. In the years since 1956, regulated peak flows at the Wilson gage have exceeded 20,000 cfs four times (in 1982, 1986, 1996, and 1997), compared to 12 times prior to 1956. However, of the 12 times prior to 1956, only one (in 1943) occurred during the period 1930 to 1956. The remaining eleven occurred prior to 1930.

Although flood control regulation has been improved by Jackson Lake operations, sustained, near-bankfull flows in the Jackson Hole area (about 10,000 cfs) probably continue to contribute to bank erosion problems in the area outside the Federal levee reach. Based on records from the two USGS gages, Snake River Near Wilson and Below Flat Creek, for the period 1973 to 1986, sustained flows exceeding 11,000 cfs occurred an average of 4 weeks each year.

Flood control regulation between Jackson Lake and Palisades Reservoir has been less than optimum due to the high priorities placed on irrigation storage at

Jackson Lake and the emphasis on flood control below Palisades Dam. It is possible that new regulation studies might demonstrate more effective use of the flood control space transferred to Jackson Lake, but unless major changes are made in Congressional authorizations for the Jackson-Palisades system and in current irrigation contracts and interstate compacts, any improvements arising from new studies would likely be marginal. The potential for peak flow reduction downstream of the Jackson Lake Dam project is also limited by the fact that Jackson Lake controls only about 38 percent of the Snake River runoff at the Flat Creek gage. To significantly improve the opportunity for peak flow reduction would require construction of additional upstream storage facilities.

b. Regulation for Minimum Flow Augmentation.

Jackson Hole is a recreational haven for thousands of visitors each year. Recreational fisheries are an important element in the all-season attraction of the region. In recent years, imported lake Mackinaw has been an important resource. Reservoir levels at Jackson Lake have been regulated to maintain optimum breeding and nursery conditions to the exclusion of native river species downstream. This has usually meant holding the pool elevation constant from October 1, the end of irrigation season and approximately the middle of Mackinaw egg-laying season, until the eggs hatch in the spring.

However, recognizing river cutthroat trout as an important resource, fisheries managers have determined that a minimum stream flow of 280 cfs from Jackson Lake is required to support a healthy population of river cutthroat trout. The optimum flow is 400 cfs, and flows above 600 cfs should be avoided. To implement this plan, the lake can be drawn down as much as 5 feet after October 1 to maintain stream flows below the dam. There is an attempt to meet the 280 cfs minimum, but no formal minimum release requirement. The Bureau of Reclamation, *Operations Manual*, dated December 1997, states in part: "If the reservoir was drawn down to the minimum flood control space on October 1 then the release is set to match inflow. If the reservoir was drawn down below the minimum flood control space on October 1 then the release can be set to a minimum of inflow or 280 cfs whichever is less. The release selected will allow the reservoir to either refill to the minimum flood control space gradually over the winter or refill as much as possible up to the minimum flood control space."

Without Jackson Lake Dam, flows would have dipped below 400 cfs in each of the last 87 years and dropped below 280 cfs in 74 of those years. Statistically, stream flows have been less than 400 cfs 21.1 percent of the time and below 280 cfs for 5.5 percent of the time.

With Jackson Lake Dam in place, there were 9 years since 1909 with average annual flows less than 1,000 cfs. The lowest year was 1977 with a average annual flow of 660 cfs. If flows above 4,000 cfs are excluded because they occurred during floods and may not have been held by a moderate size dam, then, there were 15 years with

average annual flows less than 1,000 cfs. Of these, 6 occurred as back-to-back pairs. Again, the lowest flow was average annual flow was 660 cfs in 1977.

During the construction of Palisades Dam in 1956, the Corps of Engineers negotiated 800,000 acre feet of non-exclusive flood control storage at the two projects with 25 percent coming from Jackson Lake and 75 percent coming from Palisades Dam. The agreement requires the Bureau to make the storage available between March 1 and May 1 each year unless the Corps and Bureau agree in advance that expected spring runoff would be better controlled by different operation.

Although snow melt forecasting has come a long way, the exact timing and quantity of runoff is still subject to considerable error. The 1997 spring runoff was nearly 50 percent greater than anticipated, forcing both dams into defensive operation and causing severe flooding downstream.

For the current study, a representative sample of flow periods was selected that reflect current operating needs of downstream irrigators as interpreted by the Bureau of Reclamation Reservoir Operations Center. Both 1992 and 1994 were classic low-flow years. The 5-year period extending from October 1991 through September 1996 appeared to provide a full range of possibilities including the 2 drought years of 1992 and 1994 as well as an unusually-high runoff year in 1996. This period was selected for further detailed analysis.

The following is a list of "Natural" Snake River Flows at the Jackson-Wilson Bridge (flows assuming no Jackson Lake Regulation), ranked by peak flow and volume:

UNREGULATED FLOWS
Snake River at Jackson-Wilson Bridge

Ranking by Peak		**Ranking by Volume**	
Date	**Discharge (cfs)**	**Date**	**Volume (KAF)**
6 06 97	34,120	6 06 97	3,970
6 02 86	32,520	6 24 71	3,565
6 16 74	30,540	6 10 96	3,414
6 13 18	30,230	6 29 82	3,369
6 10 96	30,090	6 02 86	3,297
6 24 71	28,170	6 02 56	3,248
6 02 56	27,550	6 16 74	3,235
6 09 81	27,530	6 21 43	3,233
6 29 82	26,070	6 09 72	3,230
6 09 72	25,590	5 26 13	3,205
6 20 17	24,790	6 13 18	3,176
5 21 54	24,430	6 14 27	3,155
5 27 28	24,240	6 13 65	3,149

6 08 12	23,420	5 27 28	3,087
6 06 57	23,330	6 06 76	3,062
6 14 27	23,260	6 20 17	3,057
6 13 65	23,210	5 21 25	2,962
5 26 13	22,060	6 08 12	2,952
6 09 89	22,060	5 29 51	2,938
5 29 51	21,930	6 16 11	2,906
6 06 95	21,670	6 17 16	2,899
5 22 93	21,670	6 10 78	2,879
6 06 76	21,450	6 01 84	2,841
6 16 11	21,380	6 05 14	2,826
6 06 52	20,800	6 11 21	2,807
6 10 78	20,530	6 11 83	2,799
6 01 84	20,520	6 07 50	2,764
6 14 53	20,480	6 06 95	2,703
6 07 50	20,350	6 13 62	2,683
6 17 16	20,290	6 06 52	2,640
6 09 70	20,230	6 06 57	2,619
5 21 25	20,120	7 04 75	2,614
6 03 48	20,020	5 21 54	2,595
6 21 43	19,980	5 15 36	2,594

UNREGULATED FLOWS (Continued)
Snake River at Jackson-Wilson Bridge

Ranking by Peak		Ranking by Volume	
Date	Discharge (cfs)	Date	Volume (KAF)
5 15 36	19,850	6 07 22	2,546
6 15 59	19,790	6 07 38	2,545
5 24 80	19,480	5 10 47	2,539
5 28 79	19,260	6 21 67	2,535
5 28 79	19,260	6 21 67	2,535
6 07 38	19,160	6 09 20	2,487
6 11 21	19,130	6 09 70	2,447
6 11 83	19,020	6 07 64	2,426
7 04 75	18,970	5 25 23	2,410
6 15 63	18,900	6 09 89	2,399
6 21 67	18,350	5 27 69	2,394
6 05 91	18,120	6 06 46	2,394
6 05 14	18,020	5 22 93	2,382
6 09 20	18,010	6 12 49	2,371
5 25 58	17,960	6 13 68	2,331
6 07 64	17,930	5 21 32	2,311
6 07 22	17,890	6 03 48	2,279

6 13 35	17,330	5 24 80	2,272
6 13 33	16,650	6 05 91	2,250
6 06 46	16,520	5 28 79	2,240
6 12 49	16,430	5 27 85	2,203
5 25 23	16,380	6 15 63	2,169
6 13 68	16,320	6 15 59	2,149
5 27 69	16,210	6 14 53	2,137
5 21 32	15,960	5 17 39	2,113
6 13 62	15,720	6 09 42	2,106
5 10 47	15,710	6 25 45	2,103
6 13 55	15,490	5 24 29	2,092
6 25 45	15,460	6 09 81	2,073
5 27 61	15,390	6 13 35	2,065
5 27 85	15,010	6 13 33	2,044
5 31 66	14,990	5 30 30	2,031
5 21 73	14,820	6 11 90	2,028
6 09 42	14,350	5 31 66	2,017
5 28 37	14,270	6 13 55	1,975

UNREGULATED FLOWS (Continued)
Snake River at Jackson-Wilson Bridge

Ranking by Peak		Ranking by Volume	
Date	Discharge (cfs)	Date	Volume (KAF)
5 13 94	14,190	5 21 73	1,952
5 24 29	13,730	6 02 44	1,935
6 11 90	13,420	6 01 15	1,917
6 03 60	13,300	5 28 37	1,900
5 28 88	12,590	5 24 26	1,882
5 30 30	12,370	5 28 19	1,851
5 28 19	12,330	5 25 58	1,821
5 17 39	11,120	5 26 41	1,818
5 26 40	11,080	5 27 61	1,806
5 26 41	10,880	6 03 60	1,805
5 18 24	10,780	5 19 87	1,780
6 01 15	10,620	5 26 40	1,733
6 02 44	10,390	5 18 24	1,707
5 24 26	10,290	5 13 94	1,642
5 08 92	9,870	5 08 92	1,640
5 19 87	9,700	5 28 88	1,617
6 09 77	8,820	6 02 31	1,433
5 07 34	8,690	5 07 34	1,399
6 02 31	8,610	6 09 77	1,328

Assuming reasonable forecasting, volume becomes a more important indicator of low-flow capability than peak flow. Not surprisingly, irrigation demands are higher in low-flow years than in normal years due to dry conditions everywhere else in the basin. The basin runoff volume for 1994 was the sixth lowest flow on record, and followed only 1 year behind 1992 which was the fifth lowest flow on record. Being recent in history and very low, 1994 was chosen as the test case for low-flow discharge.[1] Irrigation demands in 1992 were considered too extreme for the present analysis.

The 1994 hydrograph of mean daily flows shown on chart 5, shows the summer runoff of July subsiding into the irrigation demand curve of August. The 1994 irrigation demand was then superimposed on the 5-year test period from October 1, 1991, to December 12, 1996, to determine if optimum low flows could be maintained.

The Hydrologic Engineering Center's model HEC-5, "Simulation of Flood Control and Conservation Systems," was used to route the flows through Jackson Lake. The following four criteria were used for annual flow routing:

- Maintain a minimum flow of 400 cfs below the dam.
- Maintain minimum irrigation flows at Jackson-Wilson Bridge equal to 1994.
- Draw Jackson Lake down to elevation 6755 by October 10.
- Do not exceed 15,000 cfs at Jackson-Wilson Bridge.

The 1994 irrigation demand curve was repeated during each year of the simulation. As the river hydrograph on chart 6 shows, a low flow of 400 cfs was maintained even during the 2 drought years of 1992 and 1994. This analysis indicated that the 400 cfs minimum could be maintained during the winter if irrigation demand was the same each year. In the draught year of 1992, the irrigation demand was considerably higher than normal, resulting in an October 1 pool level that was several feet lower than would normally occur at this time of the year. It was so low that it would not have been possible to refill the reservoir if 400 cfs had been released during the fall and winter months. Based on the analysis to date, it appears that the 400 cfs could be maintained during normal flow years, but that during drought years similar to 1992, this level of release could not be achieved while still meeting the irrigation demands for the following year. It should be emphasized that the Bureau of Reclamation operates Jackson Lake Dam. They are in a better position to consider all of the operational constraints, and should be the agency that makes the final determination whether additional winter-flow augmentation is possible.

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[1] Idaho fisheries managers are lobbying for a mandated minimum pool in American Falls Reservoir. If they succeed, less water may be available from American Falls for downstream irrigators and more water may be taken from upstream projects such as Jackson Lake.

13. HYDRAULIC ANALYSIS.

a. Mathematical Sediment Transport Modeling.

Determination of the amount of sediment that is transported through the study reach on an average year and during a major flood event would have been a useful bit of information. This information, along with a reasonable evaluation of sediment erosion and deposition, would have provided estimates of the quantity of sediment that could be removed from the system. Unfortunately sediment transport and deposition on this reach of the river is very complex and difficult to determine. During a major flood, the flow is spread across a braided channel system that may look more like the teeth of a saw than a typical channel section. Along the same cross section there may be one or more areas of flow concentration where velocities may reach 10 to 12 fps. There are other secondary currents that may be moving at 3 to 4 fps, and intermediate areas of shallow overflow, where velocities are anywhere from 0.5 to 3 fps. Sediment is likely to be eroded from one bar that is exposed to a high-velocity current, then be redeposited a short distance downstream where the flow escapes over the side of the channel. At other locations the sediment may fill in the channel and then spread out over the surrounding over bank areas. The situation can be very fluid during a major flood. Local residents have reported watching the current shift from the levee on one side of the river to the levee on the other in a matter of hours.

As part of this study, attempts were made to estimate the quantity of sediment that could be transported by the river in an average year by first calculating the initial transport capacity, and then running a computer simulation for an extended period of time to determine the equilibrium transport rate. The Hydrological Engineering Center's program *Scour and Deposition in Rivers and Reservoirs (HEC-6)* was used for the simulation. Widely varying values were calculated depending on the formula used and the reach of the river being used as a transport reach. Using the reach from the Gros Ventre downstream to Site 9 resulted in an estimated equilibrium transport of over 450,000 cy per year.

Numerous runs were also made in an attempt to determine the pattern of erosion and deposition with and without the restoration features for a typical year and for a period of 6 years in the future. Plates 36 and 37 show the results of one modeling effort at Site 9. The dark areas along the channel-bottom profile indicate sedimentation, while the light areas indicate erosion. Although a reasonable pattern was achieved on some trials the model was far too unstable to be considered reliable. The average cross section velocities, calculated by the model, were apparently far too low to transport the gravel sizes that are known to be transported. Due to the complexity of the flow patterns and lack of confinement of the flow, it does not appear possible to accurately model the sediment transport with a mathematical model. A 2-dimensional model would reproduce the instantaneous velocity distribution better. However, due to the channel complexity, and major channel boundary changes, it is unlikely that it would be successful. Although considerable effort was expended on this

portion of the study, the results of the mathematical analysis did not appear to be accurate enough to justify the time and space required to include them in this report.

Experience obtained by monitoring the project and observing the effect of various restoration measures will likely provide a much better indication of the system response than could be obtained with any modeling effort.

b. Results of Computer Modeling of Flood Flows.

Hydraulic modeling of the Snake River in each of the study areas was performed using HEC-2, a computer-backwater model developed by HEC. Some of the same stability problems and difficulties with divided flow are inherent in this model. However, modeling flow is less complex than sediment transport modeling, and there was some surveyed high-water-mark data available for model calibration.

This part of the study was needed to determine the effect proposed measures would have on water levels during a major flood. Most of the channel modifications would fall within the regulatory flood-way as delineated by the Federal Emergency Management Agency in their May 4, 1989, Teton County Flood Insurance Study (FIS). The area is designated as a no-rise area. Meaning that actions within or adjacent to the floodway should not result in a rise in the regulatory, 100-year flood water-surface profile. The 1989 Teton County Flood Insurance Study used a peak-discharge frequency table, which listed the 100-year flood as 23,300 cfs. More recent calculations suggest that the 100-year flood should be closer to 29,000 cfs. However, since a comparison must be made with the FIS regulatory profiles, all of the comparisons in this section of the report are based on the 1989 FIS frequencies. The approximate location of the regulatory floodway boundaries for Areas 1, 4, and 10 are indicated on plates 32, 33, 35. The levees mark the floodway boundaries for Area 9. It should be noted that the Flood Insurance Study was based on 1973 surveys, and the study results were based on computations using an older model of the HEC-2 program that does not compare well, in some areas, when run with a more recent version. Considerable changes have also occurred in both the channel and adjacent wooded islands since 1973.

Mathematical modeling of this river is very difficult. The flow-pattern is braided; the channel bed is constantly changing; and the river does not flow in the same channel from year to year. The length of the flow path has significantly changed over the years in some areas. A further complication is that flow over much of the channel at the 100-year flood level is at or near "critical", a hydraulic condition in which a very small disturbance can result in a large change in the water surface elevation. Gravel bars and accumulations of debris can cause local variations in the water surface. At certain levels, a very small change in the trial water surface results in a very large change in the surface area covered by the water. This results in instability in the mathematical model. The braided nature of the channel results in divided flow conditions where flow in one channel can be several feet above that in another channel along the same cross section. Another serious problem is the width of the cross

sections combined with the steep slope of the valley. A slight change in the cross section angle creates an artificial tilt in the cross section profile creating an artificial increase in capacity along one side of the cross section. Due to these and other similar problems, a high degree of reliance should not be placed on the results of the mathematical analysis. Discrepancies of up to two feet can be expected in some areas, and a difference of up to four feet has occasionally been found in areas where major channel changes have occurred or where divided flow exists. Since the river is constantly changing, the modeling results, at best, represent conditions at one point in time.

One of the first steps in setting up the model was to attempt to calibrate it to high-water marks that were observed during the 1997 peak flood. These elevations are listed on table 5. During the 1997 flood, a peak flow of 32,027 cfs was observed at the USGS gage "Snake River Below Flat Creek." This flow was well in excess of the calculated 100-year flood level, and the flow almost certainly caused changes in the channel geometry. Unfortunately, at the time when these studies were performed, the most-recent surveys were completed prior to the 1997 flood. Five cross sections were surveyed in 1996 within each of the four restoration areas. In addition, 2-foot contour maps, based on 1996 aerial photography, were available. Extensions of the hydraulic models upstream and downstream of the recently-surveyed area required the use of older surveys performed in 1988. The river has obviously changed course and considerable gravel movement has occurred since 1988. How much error was introduced by these changes is not known. A partial 1998 survey, covering parts of Area 1 and Area 4, became available just as this report was being completed. A preliminary review of this survey indicates that the 1997 flood resulted in major channel changes in both areas. In addition, a considerable volume of sediment appears to have accumulated in the upper half of Area 4 in the 10-year period since 1988. Additional analysis will be required to confirm this observation.

The next step in the analysis was to determine the effects of channel modifications resulting from implementing the restoration measures. An attempt was made to model the worst case with respect to restoration-effects on the water-surface profile. Brush fences were assumed to be totally effective in blocking flow, and an estimated 50-year growth of vegetation was assumed. The structural design of the fences was based on considerations of static loading and observed point velocities, rather than the results from HEC-2 modeling. The average cross section velocities, calculated by the HEC-2 model, were not considered representative of local conditions at the structures.

The results of the Hydraulic Analysis are indicated on plates A1-1 through A10-12 and tables 6 through 17. The plate numbers were designated in this manner in order to separate the groups of plates by Restoration Area. Plates A1-1 through A1-20 are all referenced to Area 1; plates A4-1 through A4-13 refer to Area 4, *etc.* The cross section locations are indicated on plates 32-35.

(1) Hydraulic Calculations for Area 1.

The results of an effort to calibrate the hydraulic model to observed a high-water mark is indicated on plate A1-1. As indicated, the computer model could not exactly match all of the observed high-water marks without introducing unrealistic roughness coefficients. Points R2 and R5 probably could not be matched without changing the geometry of the cross sections. In fact, major channel changes did occur between the channel surveys and the high-water mark survey as a result of the 1997 flood. Local anomalies such as divided flow, local flow stagnation, or even surveying or high-water-mark identification errors could have contributed to the differences. An attempt was made to use the same range of Mannings-n values as was used in the HEC-2 model for the Flood Insurance Study for areas that were covered with similar vegetation. A value of 0.04 was generally used for brush-free areas of the main channel. Values ranging 0.04 to 0.15 were used in the over bank areas with the higher values used for very dense brush and forested areas. Mannings-n values, as low as 0.35, were used for some clean secondary channels. Since major changes had occurred since the FIS study was performed, aerial photographs, taken in 1996, were used to identify channel characteristics and over-bank vegetation density and distribution.

In order to estimate the effect of restoration measures on the water surface profile, hydraulic models were developed with, and without the effects of the restoration measures. The general layout of Area 1, including restoration measures and cross sections used for this model is shown on plate 32. The channel cross sections with and without restoration measures are shown on plates A1-5 through A1-20. The water surface profiles are shown on plate A1-2 through A1-4. It should be noted that the 100-year profile representing the 1996 existing condition was generally above the profile that was calculated using the FEMA model which was developed for Flood Insurance purposes. This difference was probably due to several factors: (1) The main channel has shifted progressively to the west, resulting in an increase in the average flow-path and a reduction in the average channel slope; (2) distances listed in the Flood Insurance Study report were generally shorter than similar distances measured on the 1996 topographical maps, with the difference amounting to a total of 1,400 feet over the length of Area 1; (3) instability in the mathematical model probably resulted in unrealistic calculated fluctuations in the water surface; and (4) flow was allowed to spread farther laterally in the 1973 model than in the 1996 model. With an average channel slope of about 16 feet per mile in this area, the water-surface difference in 1,400 feet would be about 4.2 feet. Distances in the 1973 hydraulic model, which served as a basis for the Flood Insurance study, were measured on uncontrolled aerial photographs. The centerline distance-differences along with a comparison of calculated water-surface elevations are summarized on table 6.

Due to the rapidly changing topography in this area, and previously discussed problems with mathematically modeling this river, it will probably be impossible to mathematically demonstrate exactly how the river will respond to the restoration measures. In any event, comparison of the profiles with and without the

restoration measures indicates that the project will result in lowering the water surface profile up to about 1 foot in the excavated areas. Although, the model indicated a very small rise between Range R5 and 108 and a larger rise at Range 109 upstream of the channel restoration work, both of these appear to be extrapolation inaccuracies in the model rather than realistic projections. The proposed locations of the fence structures are either in areas which already have mature vegetation or which were formerly covered by heavy riparian growth and have since eroded away. (Compare proposed brush-fence locations shown on plate 32 with areas eroded since 1973 shown on plate 28). Controlled gravel removal and a modest shortening of the channel should shift a portion of the flow back toward the center of the meander belt and should shift the river regime slightly toward channel entrenchment. These measures should result in increased channel stability and reduce the risk of continued flooding and bank erosion. The restoration measures in this area are not expected to result in a rise in the 100-year flood profile.

(2) Hydraulic Calculations for Area 4.

Area 4 represents a reach just downstream of the Federal Project Levees bounded to the east by the Upper Imenson Levees and to the west by a high terrace. The plan view of this area is shown on plate 33. Also shown on this plate are the cross section locations, proposed restoration measures, and the approximate location of the regulatory floodway. Plate A4-1 indicates the water-surface profile calculated by the hydraulic model compared with the 1997 observed high-water marks at the peak of the 1997 runoff period. The peak flow was 32,027 cfs. It should be noted that little, and in some places, no freeboard existed on the Upper Imenson Levee just downstream of the Federal Project levees. Only flood-fight efforts prevented flow from escaping behind the levees. It should also be noted that the high-water marks differ by as much as 3 feet from the left to the right side of the same section. Obviously, the HEC-2 model, which calculates a flat water surface across the cross section, does not reproduce the complicated flow regime in this area. It can only be used to roughly estimate the relative effects of the restoration measures. Mannings-n roughness values selected for vegetation-free areas of the channel were generally 0.04, and over bank values generally ranged from 0.04 to 0.12 with the higher values representing very dense brush and forested areas that were essentially non-effective flow areas. In a few locations, an n-value as high as 0.15 was used, while a value as low as 0.035 was used for some clean secondary channels. An attempt was made to avoid deviating significantly from the range of values used in the previous Flood Insurance Study for vegetation of similar densities.

Plates A4-2 and A4-3 indicate the calculated effects of the restoration measures on the water-surface profile. The calculate water-surface profile (without and channel modifications) was above the Flood Insurance Study profile at ranges 0.2, 0.1, and 1. The proposed restoration measures would lower the 1996 existing profile at or below the regulatory level for all areas within the restoration area. However, there is a rise in the calculated profile of 0.4 foot at range 1.0 that is well above any channel modifications. Again this rise appears to be related to instability in the mathematical

model, rather than an actual rise. These calculations are summarized and compared with the 100-year regulatory values on table 7. Plots, indicating the hydraulic effects of restoration measures on the channel cross section, are shown on plates A4-4 through A4-13. The effects on the 100-year water-surface are also indicated on these profiles. Tables 12 and 13 indicate calculated velocities with and without the restoration measures.

(3) Hydraulic Calculations for Area 9.

Area 9 is confined between continuous levees on both sides. These levees mark the boundaries of the FIS regulatory floodway. Plate 34 shows a plan view of this area along with proposed restoration measures and cross section locations used in the hydraulic modeling effort.

Plate A9-1 indicates the results of an effort to calibrate the model to two sets of observed water-surface elevations. It will be noted that the calibrated profile matches the water-surface elevations observed during the 1996 cross section survey much better than during the 1997 flood peak. It is likely that channel erosion during the 1997 flood resulted in an observed water-surface profile that was lower than the calculated profile. The observed elevations for the 1997 discharge of 32,000 cfs actually appear to be close to, or perhaps even lower than, some points in the 23,000 cfs FIS profile. (Compare table 5 with the profile on plate A9-2). It should be noted that the FIS profile was based on 1973 topography and uncalibrated roughness coefficients. Due to the above differences, it was decided to disregard the roughness values used in the previous FIS model, and to select the roughness values based on comparisons with surveyed water-surface information and engineering experience. Selected Mannings-n values varied from 0.030 to 0.045 for the channel and from 0.04 to 0.08 for over bank areas.

Based on the observed water surface profiles, combined with the results of the hydraulic modeling in this area, it does not appear that the restoration measures will result in any rise above the regulatory 100-year profile. A rise in the calculated profile at Range 13 (see table 8), which is upstream of the restoration area appears to be due to instability in the mathematical calculations rather than an expected actual rise in the water surface. (A high, calculated, friction-slope at the upstream end of Range 12 is projected upstream, apparently resulting in overshooting the elevation at Range 13 and undershooting at Range 14. Adding more cross sections can sometimes reduce this type of oscillation and instability in the model).

The hydraulic effects of proposed channel-capacity excavation and brush fences are indicated on plates A9-3 through A9-16.

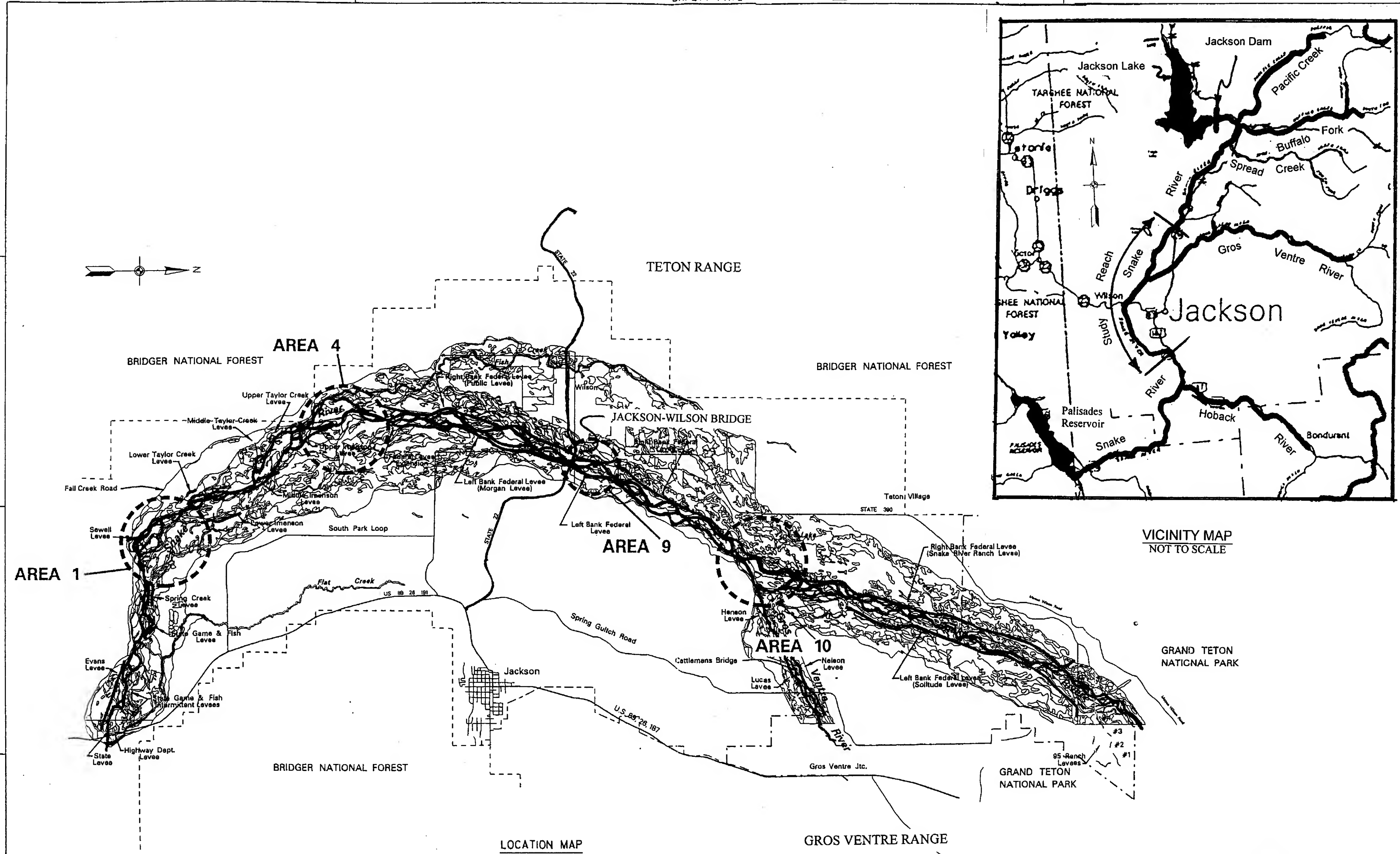
(4) Hydraulic Calculations for Area 10.

Area 10 was rather difficult to model due to the highly braided nature of the river and the existence of separate channels along each side of the riverbed. The channels on the right bank are several feet higher than on the left and there are

connecting channels, which allow some exchange of flow. During the 1997 runoff period flow in the right bank channel broke through the middle of the adjacent wooded island and began to flow across into the lower channel to the east. An initial effort was made to calibrate a divided-flow model. The results of this calibration effort are indicated on plate A10-1. It was relatively easy to raise or lower the model profile along the west side of the river simply by introducing more or less flow into the western branch. The divided-flow model was later abandoned, since it could not be directly compared with the FIS model. The FIS model treated the river as a single channel. Results for Area 10 shown on the remaining tables and plates were based on a single-channel model. Selected roughness values varied from 0.30 to 0.040 for the channel and from 0.05 to 0.1 for over bank areas. These were based on the judgement of an engineer experienced in river modeling.

The location of cross sections, sediment traps, and other restoration measures are indicated on plate 35. It should be noted that the hydraulic model did not capture the effect of the excavation between Ranges 22 and 28 since no cross section runs through this area. Plate A10-2 indicates the modeled water-surface profile with and without restoration measures. Both the existing and the restored channel profiles are below the FIS 100-year profile in this area. If the gravel excavation at the Gros Ventre confluence had been included, it would have lowered the restored channel profile at Range 28. In time, erosion and entrenchment of the channel, resulting from the gravel removal, would lower the profile at Range 22 as well. The long-term effect of the confluence sediment trap would be to locally concentrate the flow and draw it eastward toward the confluence, allowing the wooded island to the west to become reestablished. The upstream sediment trap combined with the brush fences is expected to reduce the flow into the existing main channel, which flows to the west around Bear Island, and develop two well-defined channels located centrally and to the west upstream of the Gros Ventre confluence. High flows through the channel that follows the levees to the west would be restricted.

Plates A10-3 through A10-12 are somewhat different than similar plates for the other restoration areas. Since the 1996 survey was taken along existing sediment range lines it was possible to indicate the erosion and channel changes that have occurred since 1973, the date when the FIS surveys were performed. The dark-shaded areas represent erosion that has occurred since 1973. The heavy line represents the existing ground and areas blocked out by the brush fences. As illustrated on plate A10-8, the fences generally block flow through areas that have been lost to erosion since 1973. Water surface profiles for the 100-year FIS profile, the existing condition, and conditions after completion of the restoration measures were also indicated on plates A10-3 through A10-12.



U . S . ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON

JACKSON HOLE, WYOMING
ENVIRONMENTAL RESTORATION PROJECT
FEASIBILITY STUDY-ENGINEERING APPENDIX
LOCATION AND VICINITY MAPS

SCALE AS SHOWN | INV. NO.

PLATE 1

REFERENCE FILES ATTACHED LEVELS ON FOR CONTRACT DRWGS SCALE

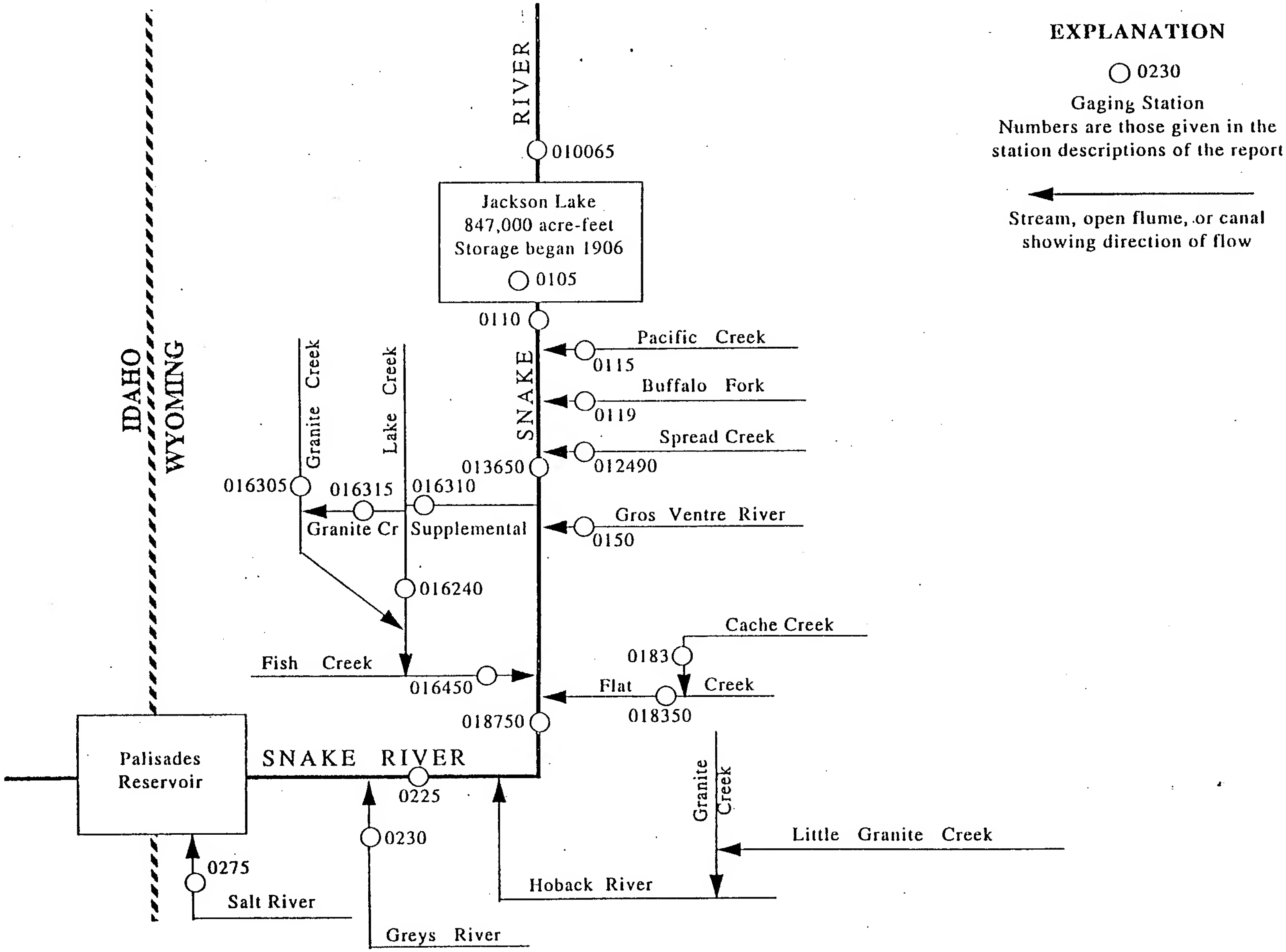
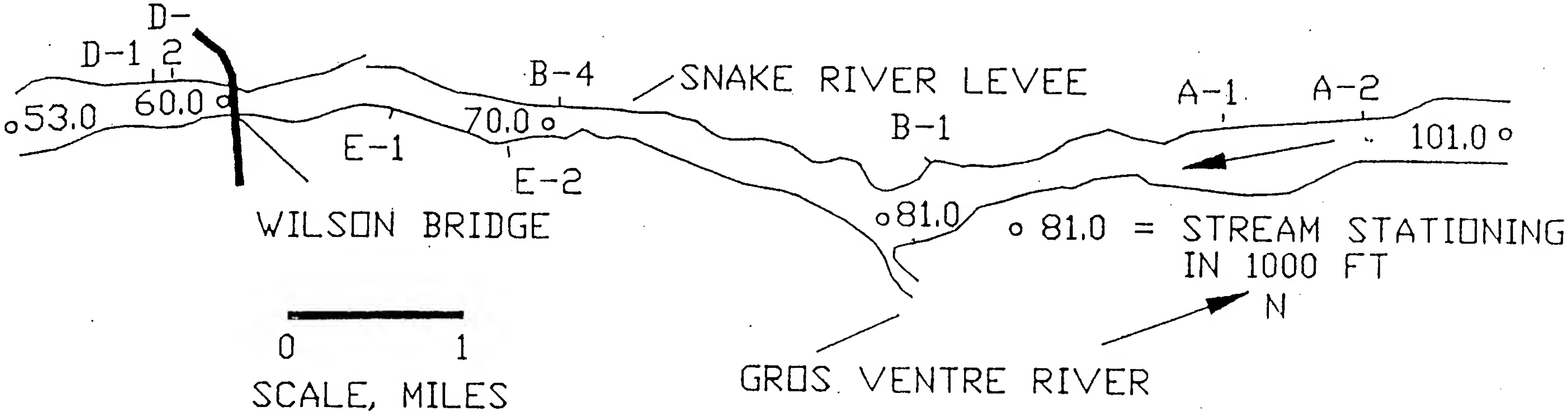


Figure 9. Gaging stations in Snake River basin between Flagg Ranch and Palisades Reservoir



SNAKE RIVER PROJECT REACH AND IMPINGEMENT SITES

Adapted from WES report Flow Impingement, Snake River Wyoming, Miscellaneous Paper HL-92," Figure 1, pg 7. Illustrations on Plates 4-12 in this report correspond to the following plates in the WES report: 5, 40, 24, 6, 41, 28, 7,44,32.

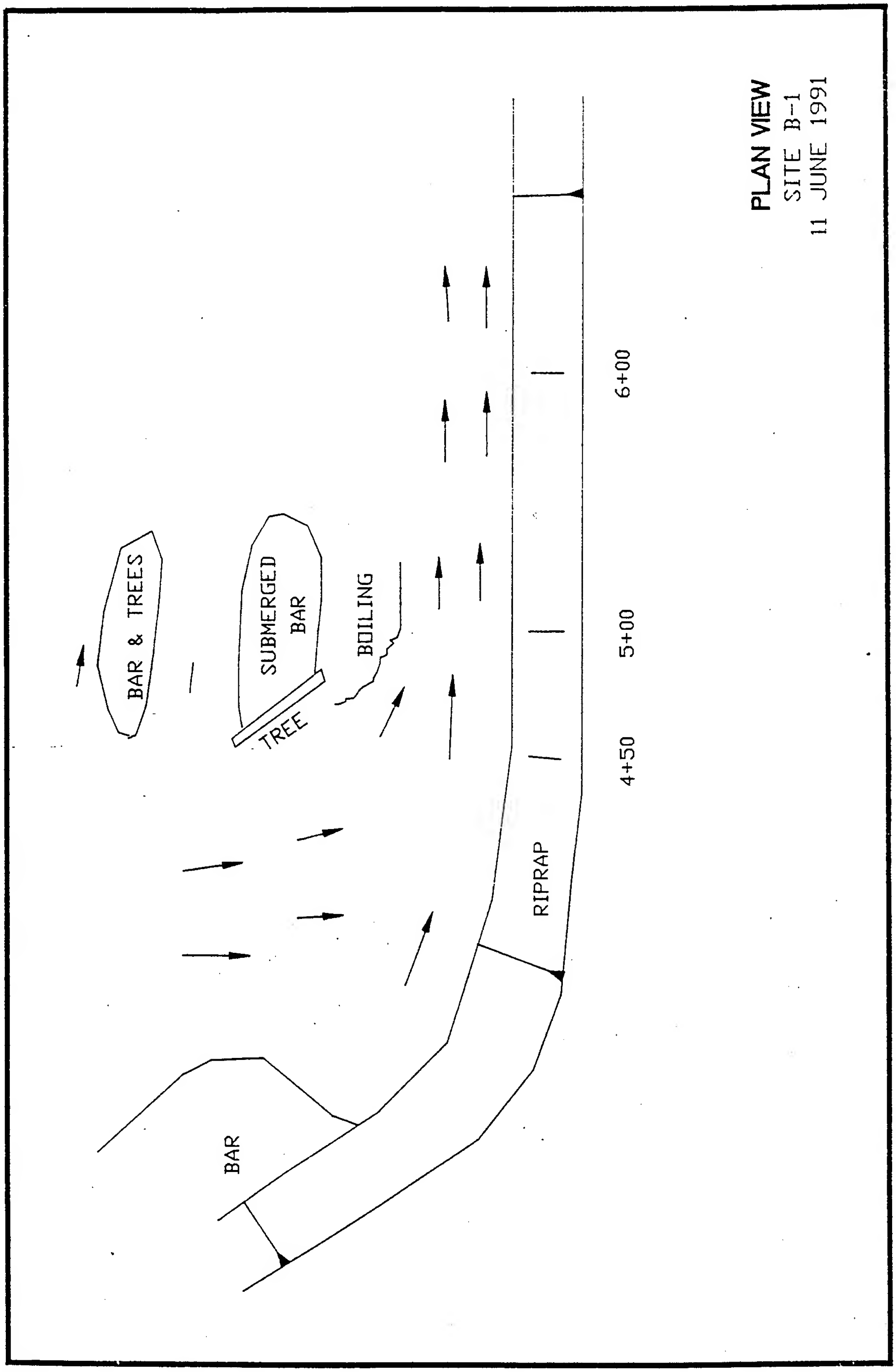

PLAN VIEW
SITE B-1
11 JUNE 1991
BAR & TREES
SUBMERGED BAR
BOILING
TREE
6+00
5+00
4+50
RIPRAP
BAR

PLATE 4

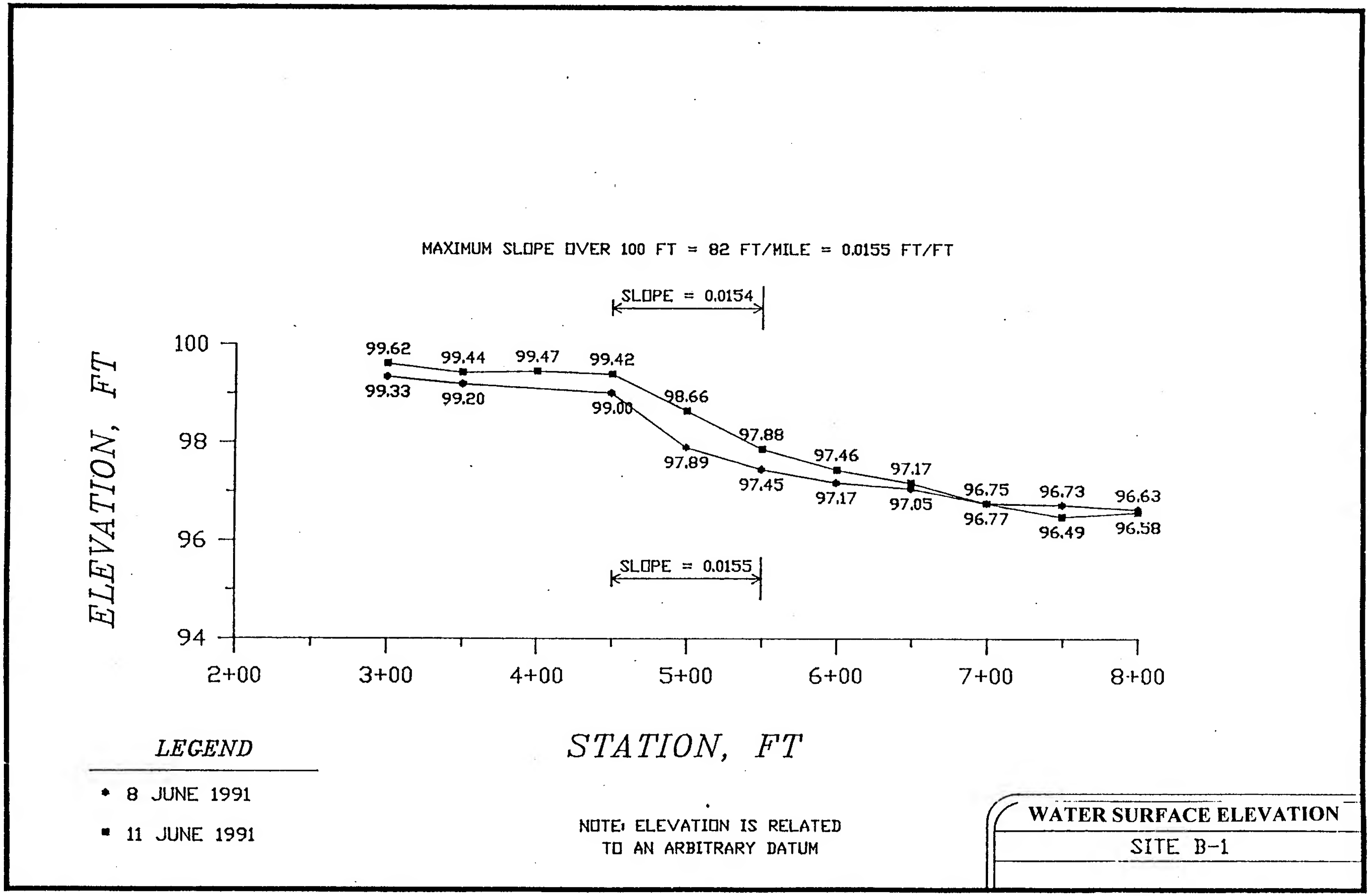
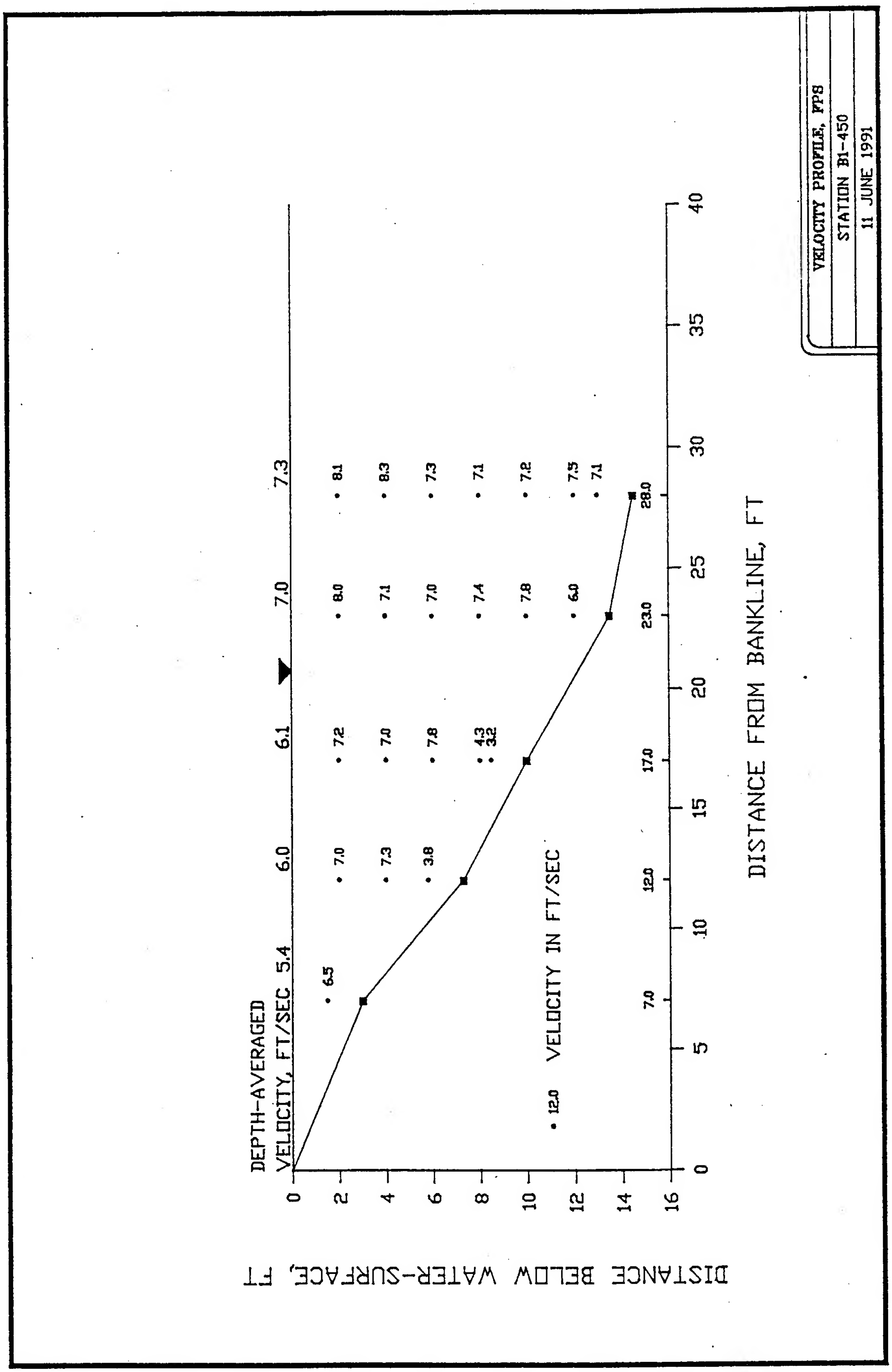

MAXIMUM SLOPE OVER 100 FT = 82 FT/MILE = 0.0155 FT/FT
SLOPE = 0.0154
SLOPE = 0.0155
ELEVATION, FT
100
98
96
94
2+00
3+00
4+00
5+00
6+00
7+00
8+00
STATION, FT
99.62
99.44
99.47
99.42
98.66
97.88
97.46
97.17
96.75
96.73
96.63
99.33
99.20
99.00
97.89
97.45
97.17
97.05
96.77
96.49
96.58
LEGEND
8 JUNE 1991
11 JUNE 1991
NOTE: ELEVATION IS RELATED TO AN ARBITRARY DATUM
WATER SURFACE ELEVATION
SITE B-1

PLATE 5



VELOCITY PROFILE, FPS
STATION B1-450
11 JUNE 1991
DEPTH-AVERAGED VELOCITY, FT/SEC
• 12.0 VELOCITY IN FT/SEC
DISTANCE FROM BANKLINE, FT
DISTANCE BELOW WATER-SURFACE, FT

PLATE 6

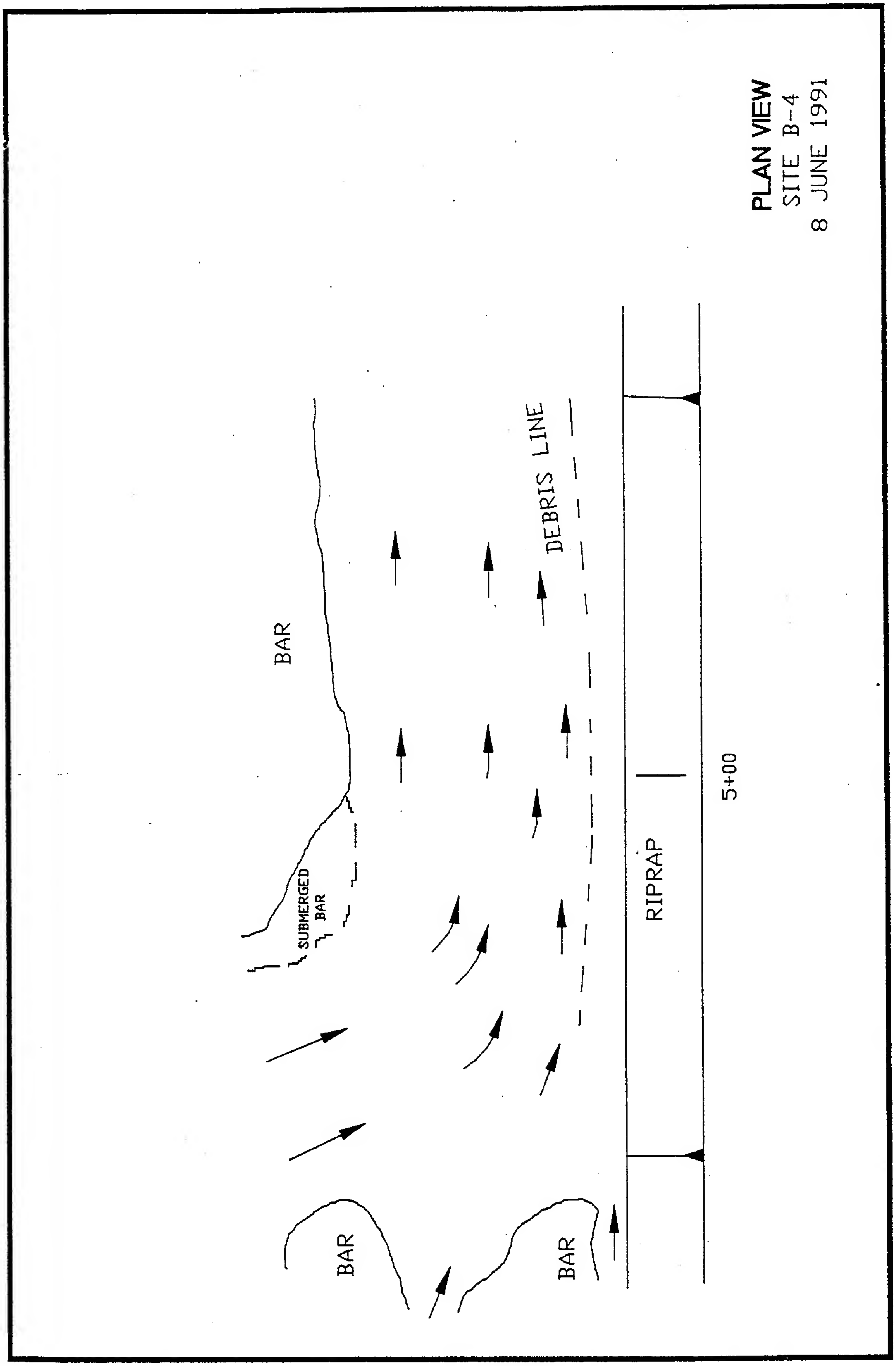
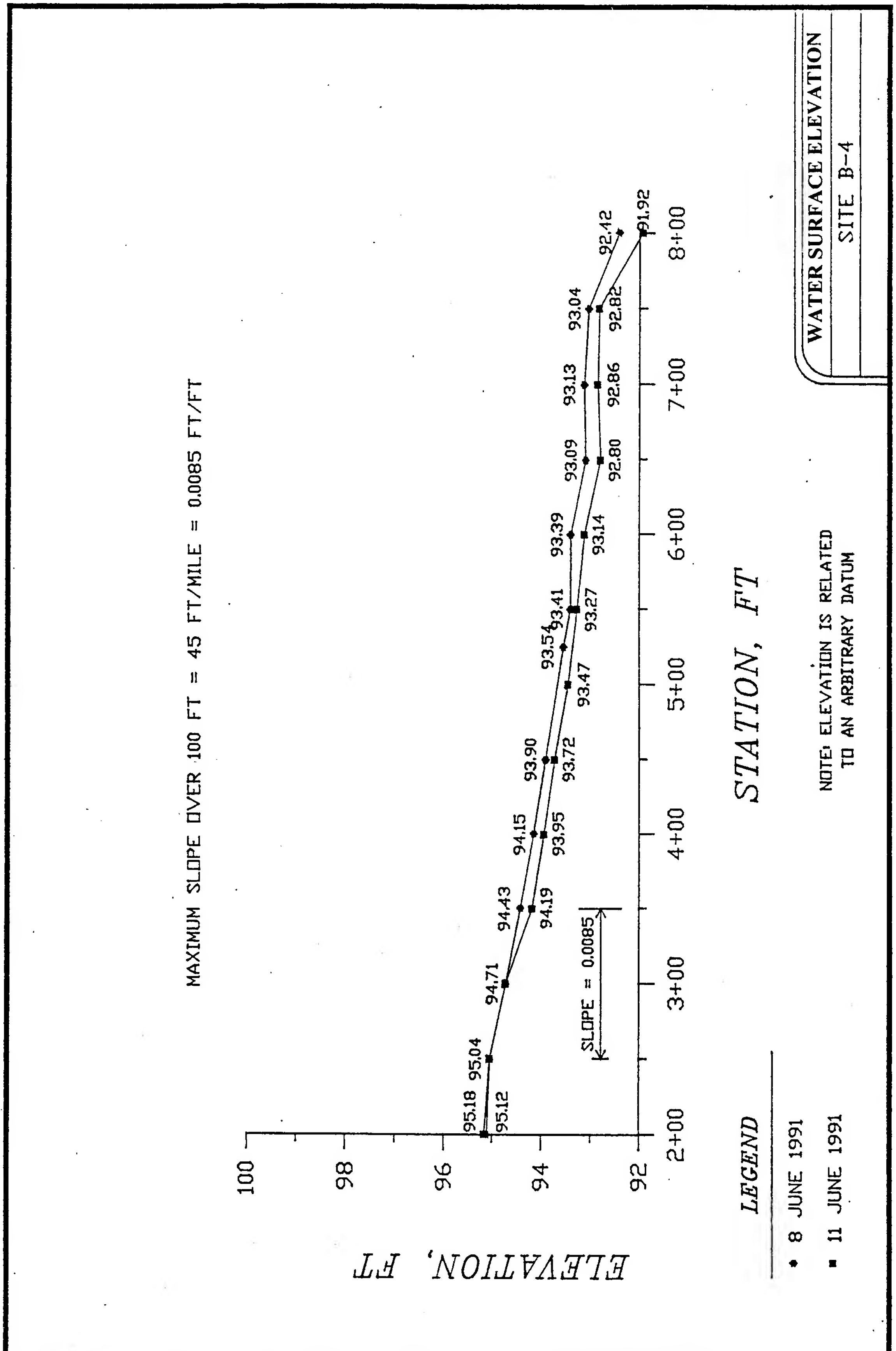

PLAN VIEW
SITE B-4
8 JUNE 1991
DEBRIS LINE
BAR
SUBMERGED BAR
RIPRAP
5+00
BAR
BAR

PLATE 7



WATER SURFACE ELEVATION
SITE B-4
MAXIMUM SLOPE OVER 100 FT = 45 FT/MILE = 0.0085 FT/FT
SLOPE = 0.0085
ELEVATION, FT
STATION, FT
100
98
96
94
92
2+00
3+00
4+00
5+00
6+00
7+00
8+00
95.18
95.12
95.04
94.71
94.43
94.19
94.15
93.95
93.90
93.72
93.54
93.47
93.41
93.27
93.39
93.14
93.09
92.80
93.13
92.86
93.04
92.82
92.42
91.92
LEGEND
8 JUNE 1991
11 JUNE 1991
NOTE: ELEVATION IS RELATED TO AN ARBITRARY DATUM

PLATE 8

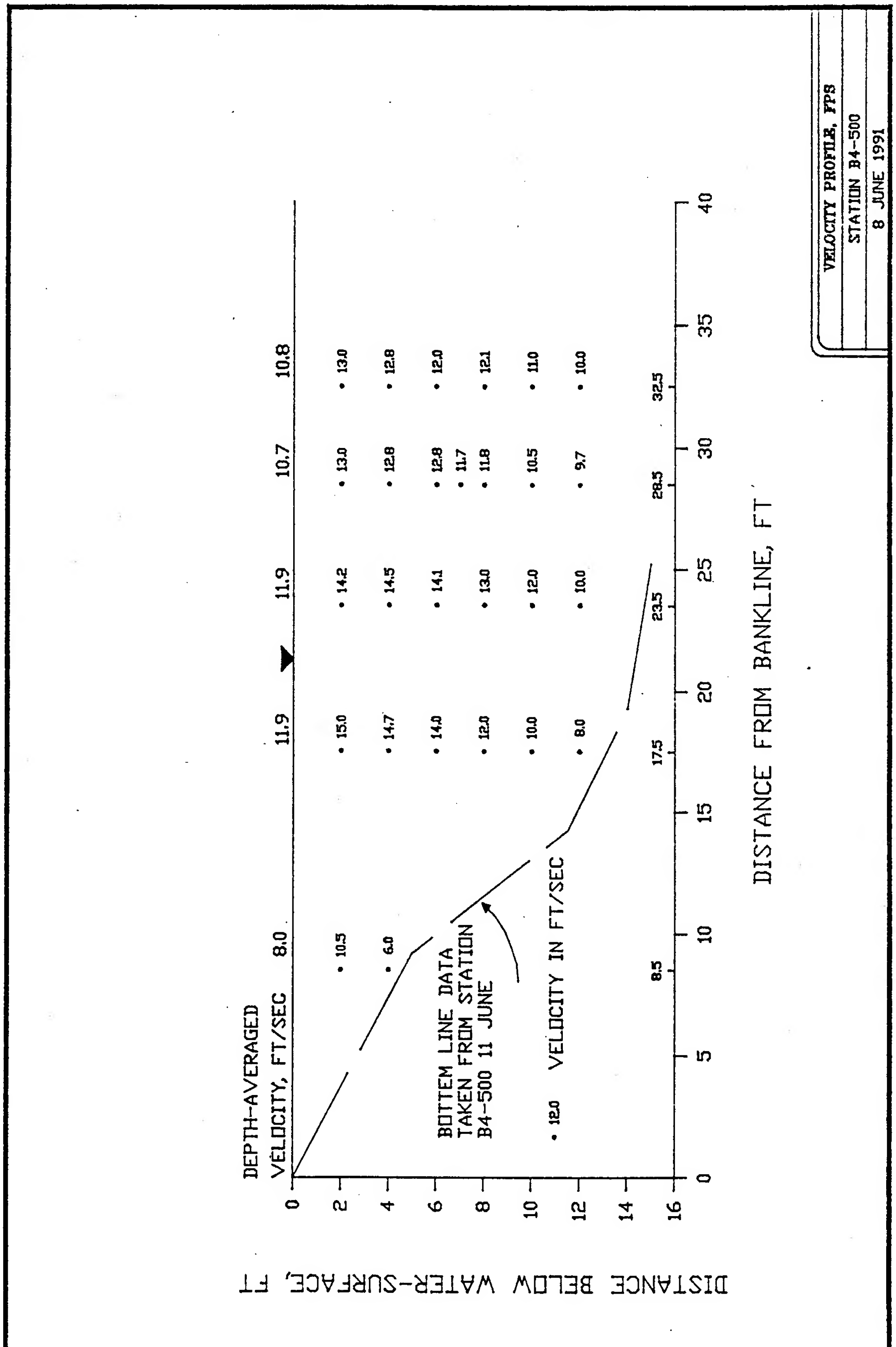
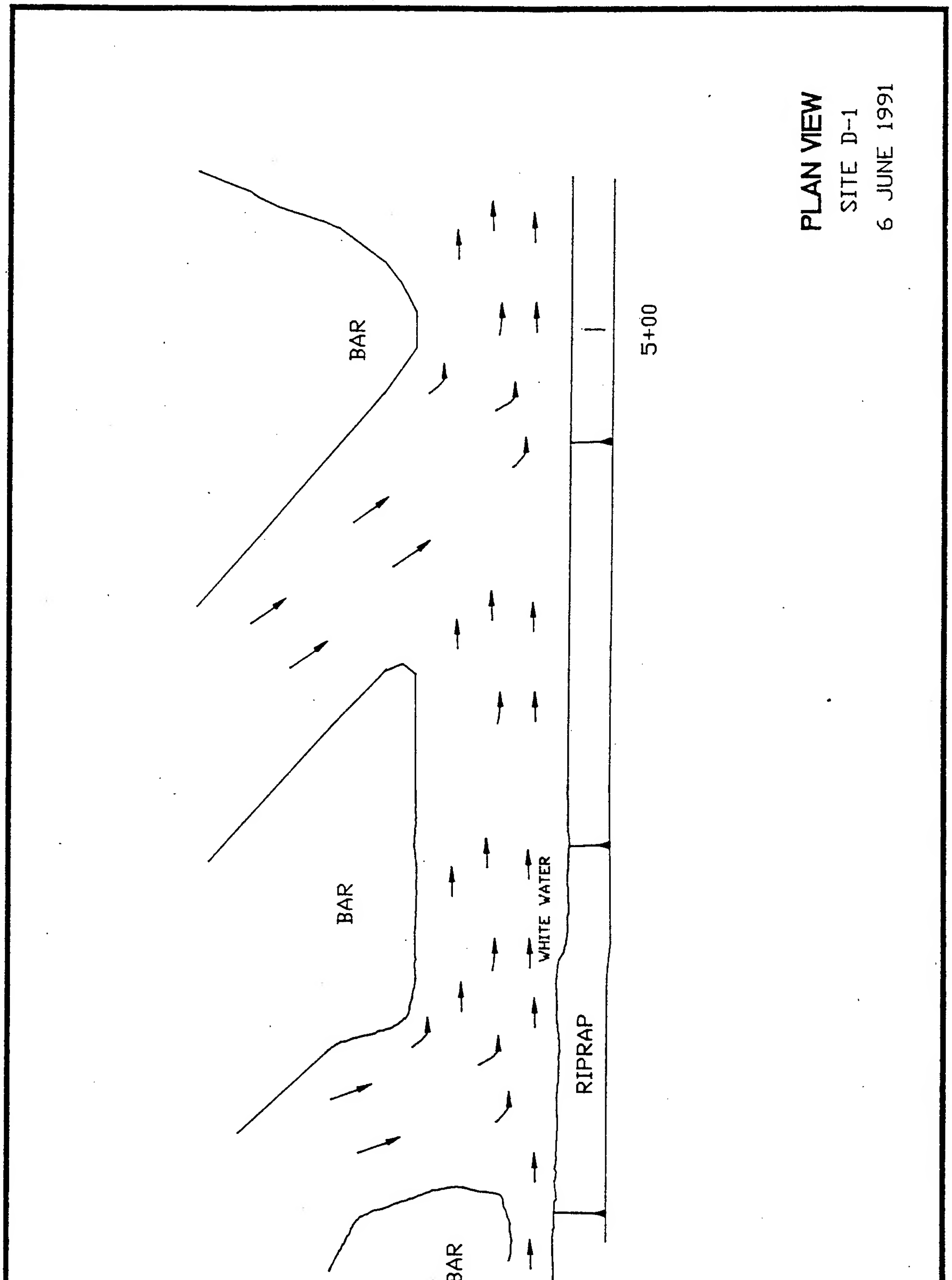
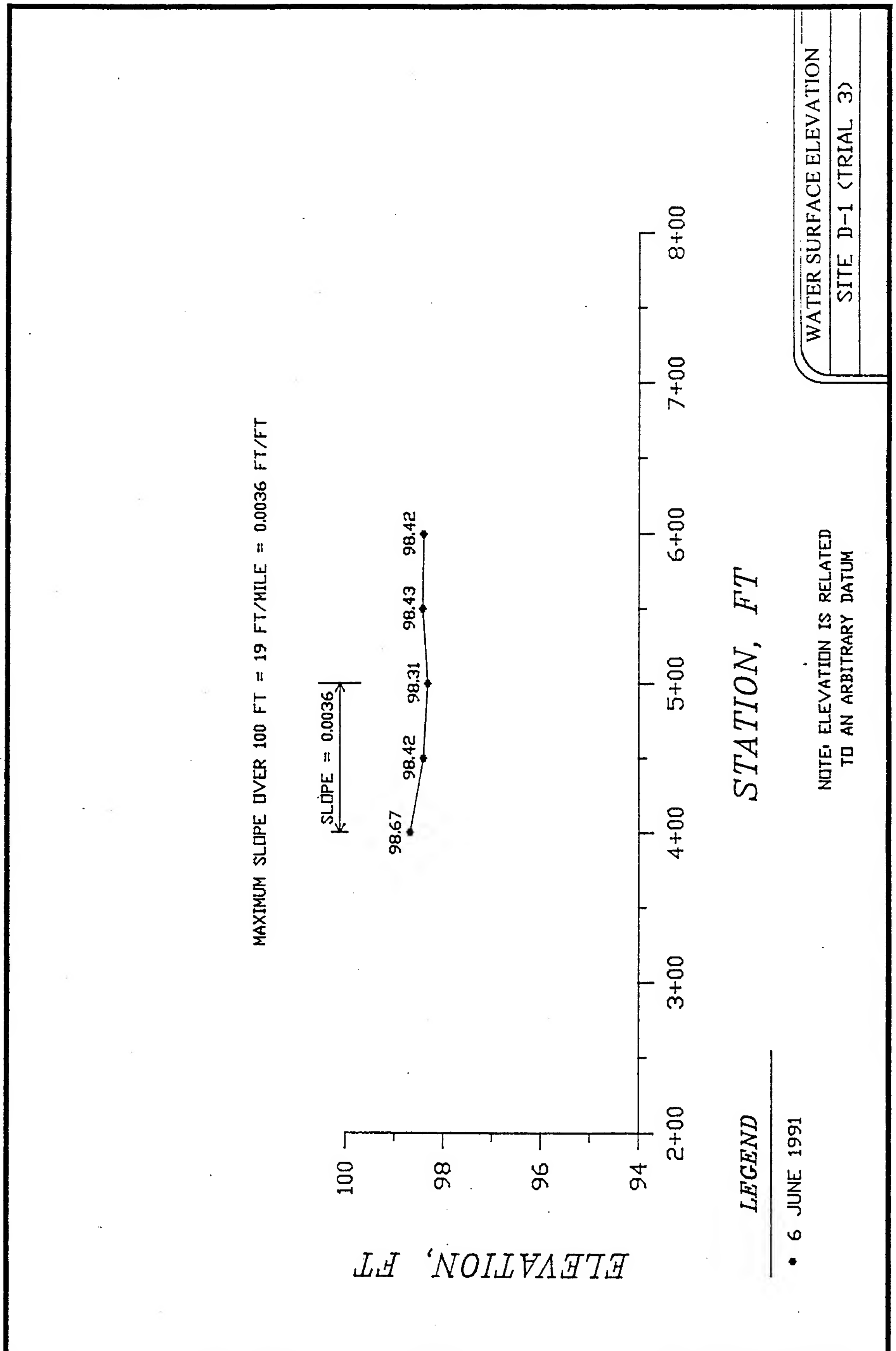

VELOCITY PROFILE, FPS
STATION B4-500
8 JUNE 1991
DEPTH-AVERAGED
VELOCITY, FT/SEC
8.0
11.9
11.9
10.7
10.8
BOTTOM LINE DATA
TAKEN FROM STATION
B4-500 11 JUNE
VELOCITY IN FT/SEC
12.0
10.5
6.0
15.0
14.7
14.0
12.0
10.0
8.0
14.2
14.5
14.1
13.0
12.0
10.0
13.0
12.8
12.8
11.7
11.8
10.5
9.7
13.0
12.8
12.0
12.1
11.0
10.0
8.5
17.5
23.5
28.5
32.5
0
5
10
15
20
25
30
35
40
DISTANCE FROM BANKLINE, FT
0
2
4
6
8
10
12
14
16
DISTANCE BELOW WATER-SURFACE, FT

PLATE 9


PLAN VIEW
SITE D-1
6 JUNE 1991
BAR
5+00
BAR
WHITE WATER
RIPRAP
BAR


WATER SURFACE ELEVATION
SITE D-1 (TRIAL 3)
MAXIMUM SLOPE OVER 100 FT = 19 FT/MILE = 0.0036 FT/FT
SLOPE = 0.0036
98.67
98.42
98.31
98.43
98.42
ELEVATION, FT
100
98
96
94
2+00
3+00
4+00
5+00
6+00
7+00
8+00
STATION, FT
NOTE: ELEVATION IS RELATED
TO AN ARBITRARY DATUM
LEGEND
• 6 JUNE 1991

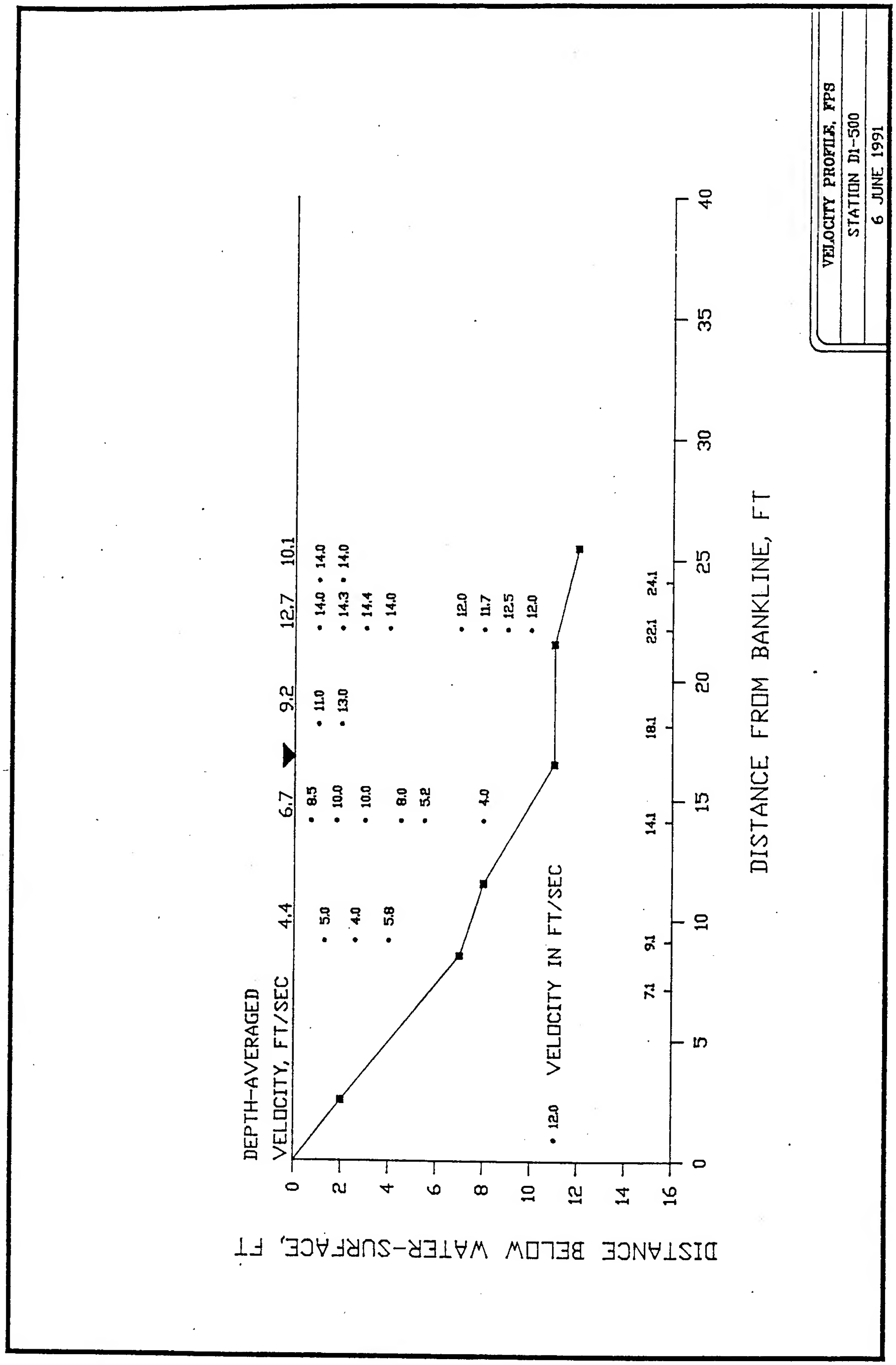
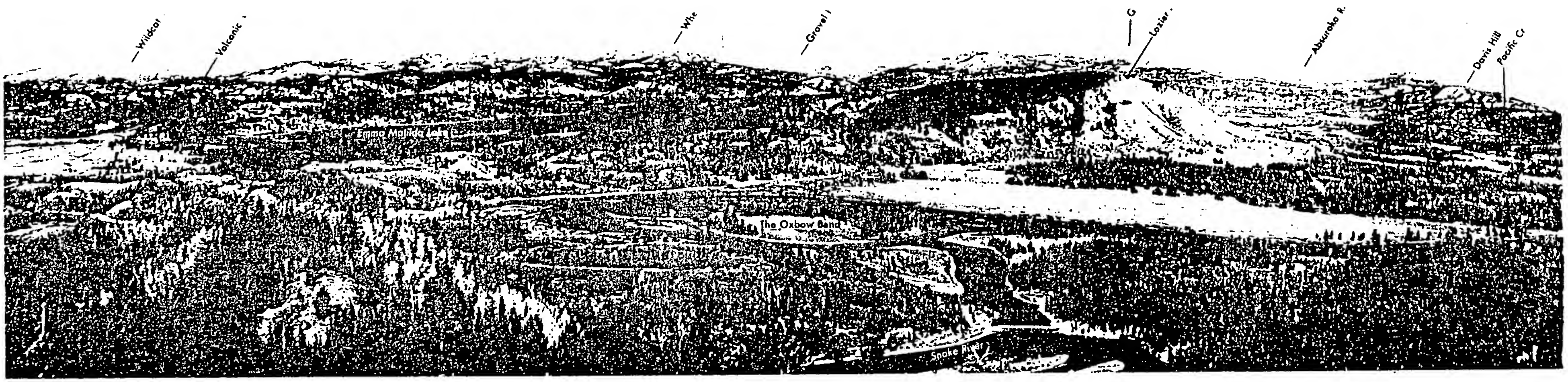
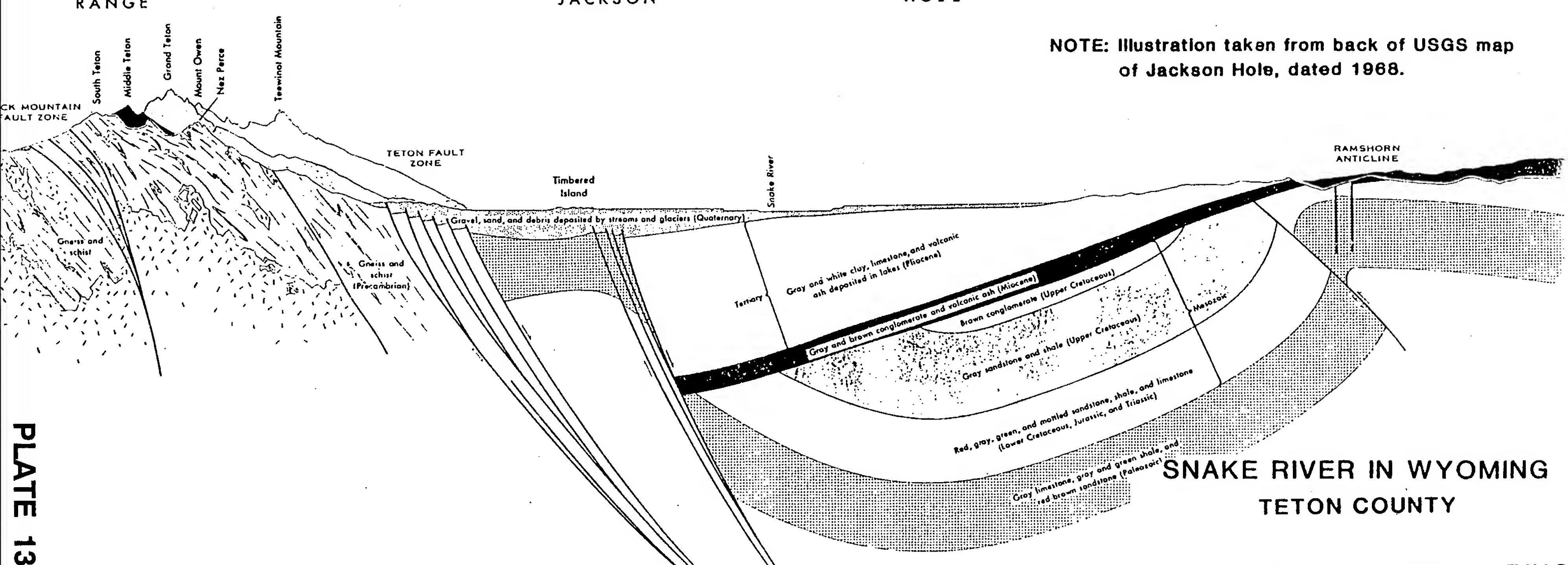

VELOCITY PROFILE, FPS
STATION D1-500
6 JUNE 1991
DEPTH-AVERAGED VELOCITY, FT/SEC
4.4
6.7
9.2
12.7
10.1
• 12.0 VELOCITY IN FT/SEC
DISTANCE BELOW WATER-SURFACE, FT
DISTANCE FROM BANKLINE, FT
7.1
9.1
14.1
18.1
22.1
24.1

PLATE 12



VIEW NORTHEAST FROM SUMMIT OF SIGNAL MOUNTAIN
Emma Matilda Lake is ponded behind glacial moraines. Most of the peaks and ridges are underlain by sedimentary rocks of Mesozoic and Tertiary age. Position of volcanic vent near Two Ocean Lake is indicated.

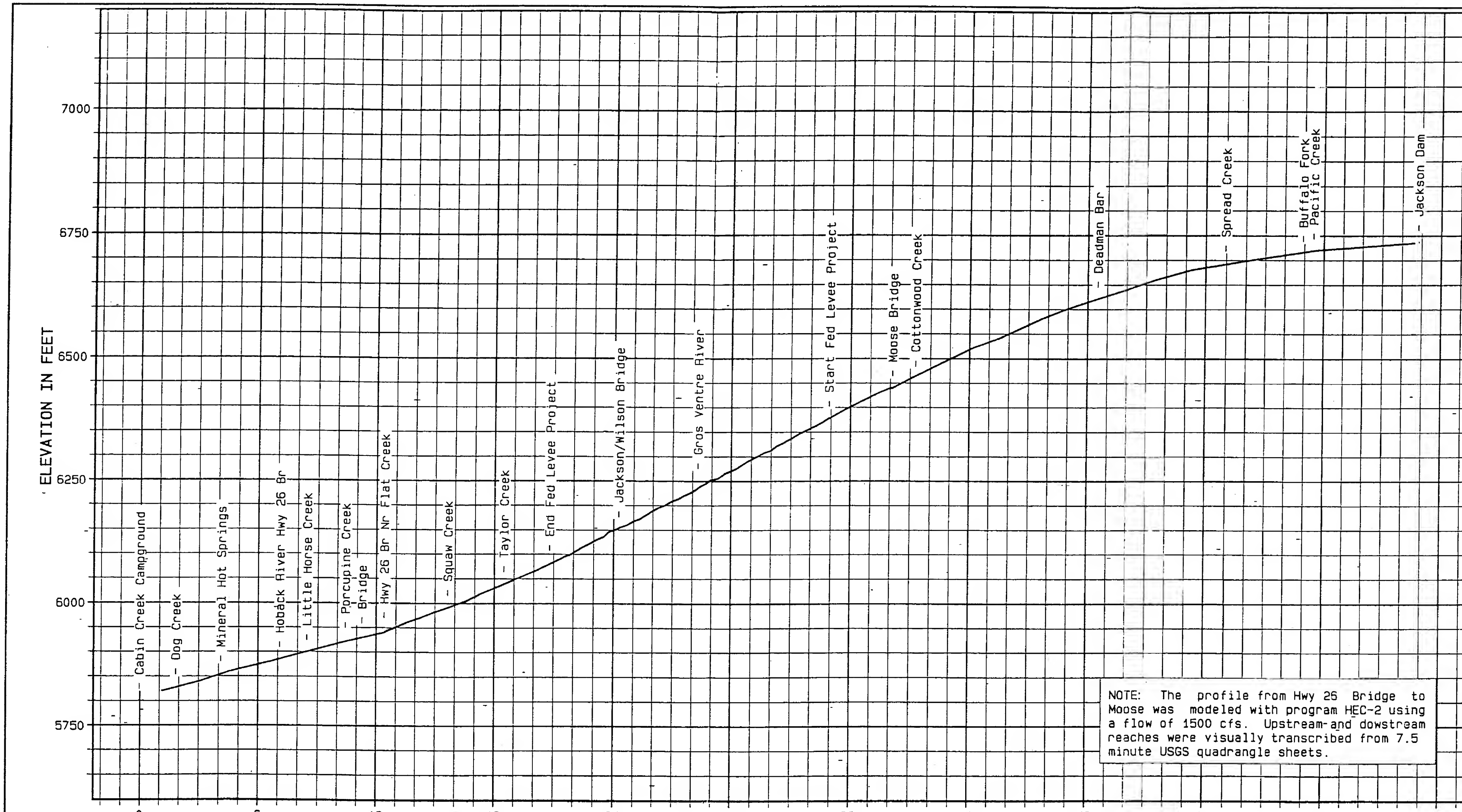


NOTE: Illustration taken from back of USGS map of Jackson Hole, dated 1968.

SNAKE RIVER IN WYOMING
TETON COUNTY

TETON FAULT BLOCK TILTING

PLATE 13

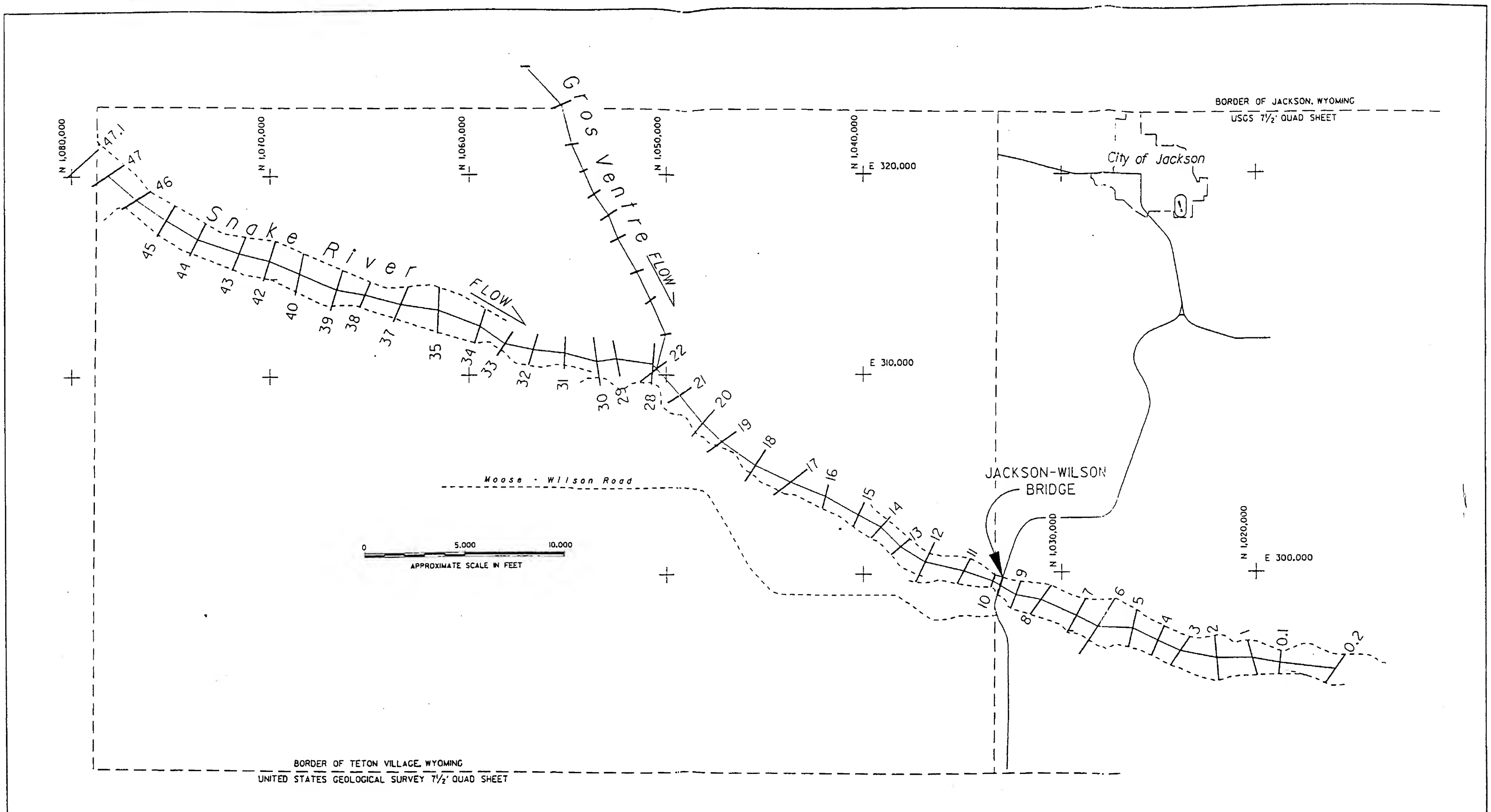


SNAKE RIVER. VICINITY OF JACKSON HOLE, WYOMING

STREAM GRADIENT
FROM CABIN CREEK TO JACKSON DAM

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

PLATE 14



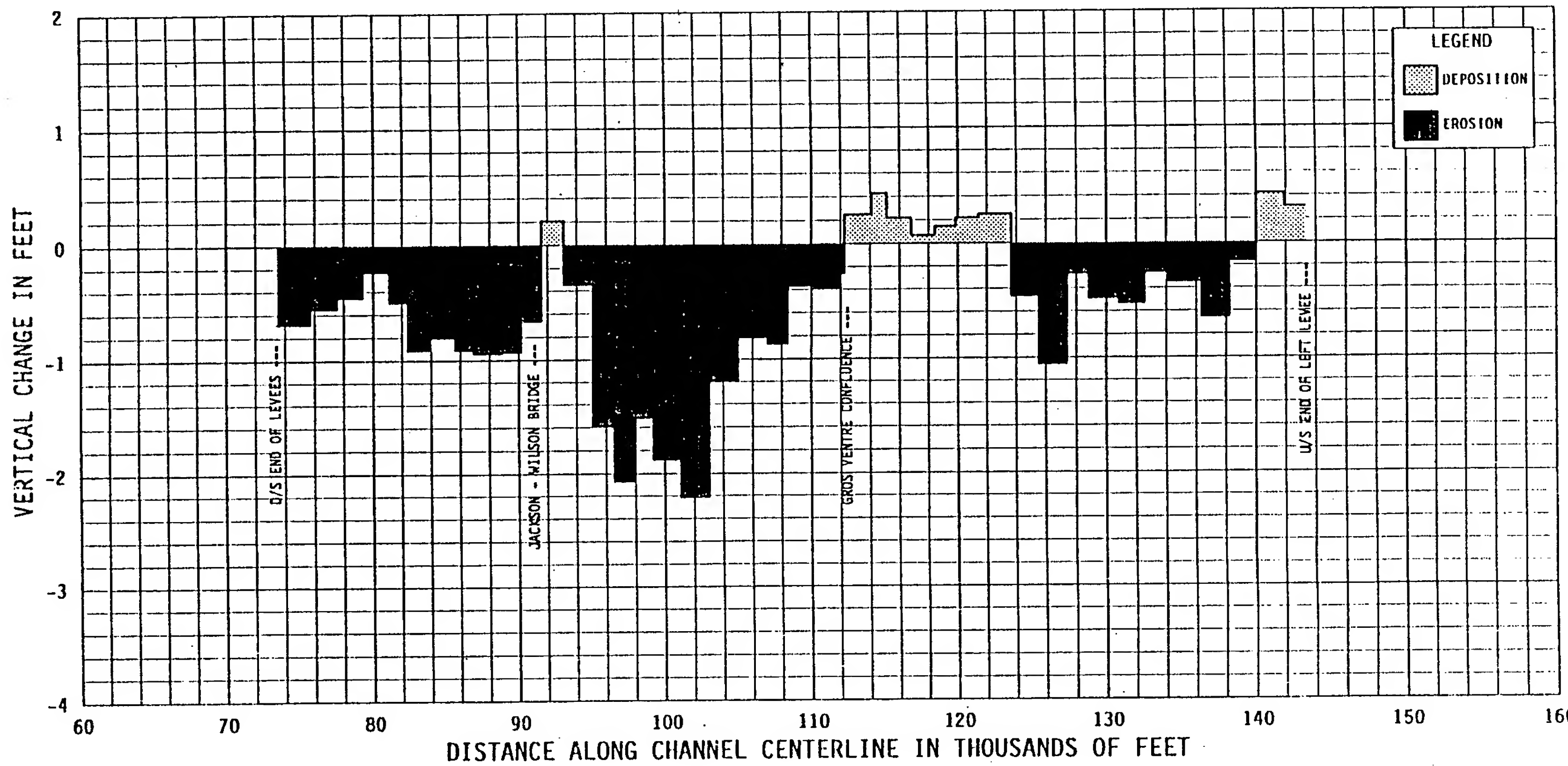
SNAKE RIVER BASIN
SNAKE RIVER NEAR JACKSON HOLE
TETON COUNTY, WYOMING

SEDIMENT RANGE LOCATIONS

U. S. ARMY ENGINEER DISTRICT
WALLA WALLA - OPERATIONS DIVISION
EMERGENCY OPERATIONS BRANCH

SHEET	DRAWN	DATE
1 OF 1	SCHUSTER	AUGUST 1992

PLATE 15



NOTES:

1. VERTICAL CHANGE IN FEET WAS CALCULATED BY DIVIDING THE VOLUME CHANGE BY THE SURFACE AREA OF THE CHANNEL BOUNDED BY THE LEVEES AND THE SEDIMENT RANGE LINES.
2. DISTANCE ALONG THE CHANNEL CENTERLINE ROUGHLY CORRESPONDS TO STATIONING ALONG THE RIGHT LEVEE IN DESIGN MEMORANDUM #1, NOVEMBER 1955.

SNAKE RIVER BASIN

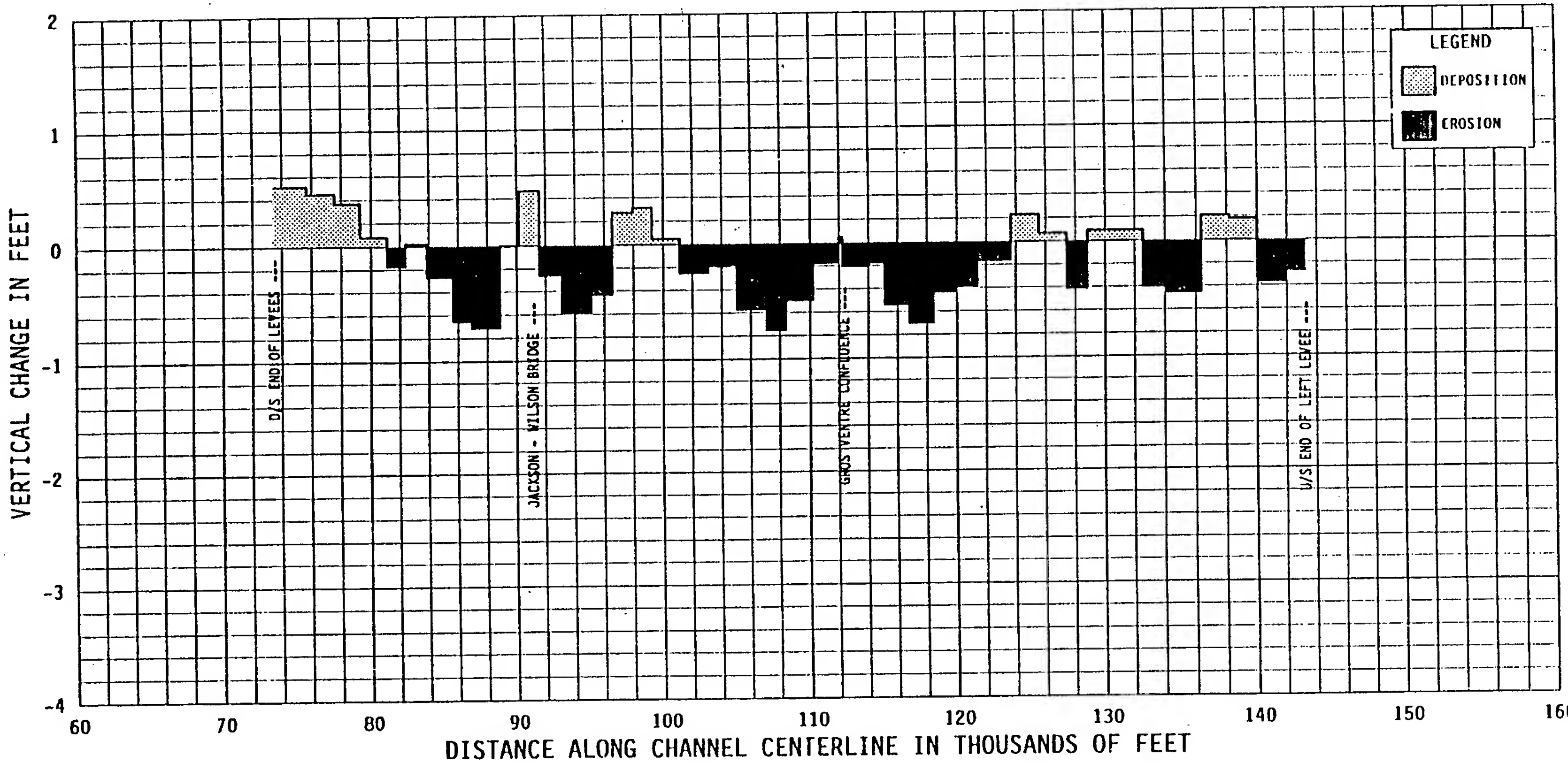
SNAKE RIVER NEAR JACKSON HOLE, WYOMING

AVERAGE VERTICAL CHANNEL BED CHANGE 1954 TO 1967

U.S. ARMY CORPS OF ENGINEERS

WALLA WALLA DISTRICT - HYDROLOGY BRANCH

DESIGNED BY:	DRAWN BY:	DATE
L. CUNNINGHAM	G. HARDIN	20 AUGUST 1992



NOTES:

1. VERTICAL CHANGE IN FEET WAS CALCULATED BY DIVIDING THE VOLUME CHANGE BY THE SURFACE AREA OF THE CHANNEL BOUNDED BY THE LEVEES AND THE SEDIMENT RANGE LINES.
2. DISTANCE ALONG THE CHANNEL CENTERLINE ROUGHLY CORRESPONDS TO STATIONING ALONG THE RIGHT LEVEE IN DESIGN MEMORANDUM #1, NOVEMBER 1955.

SNAKE RIVER BASIN

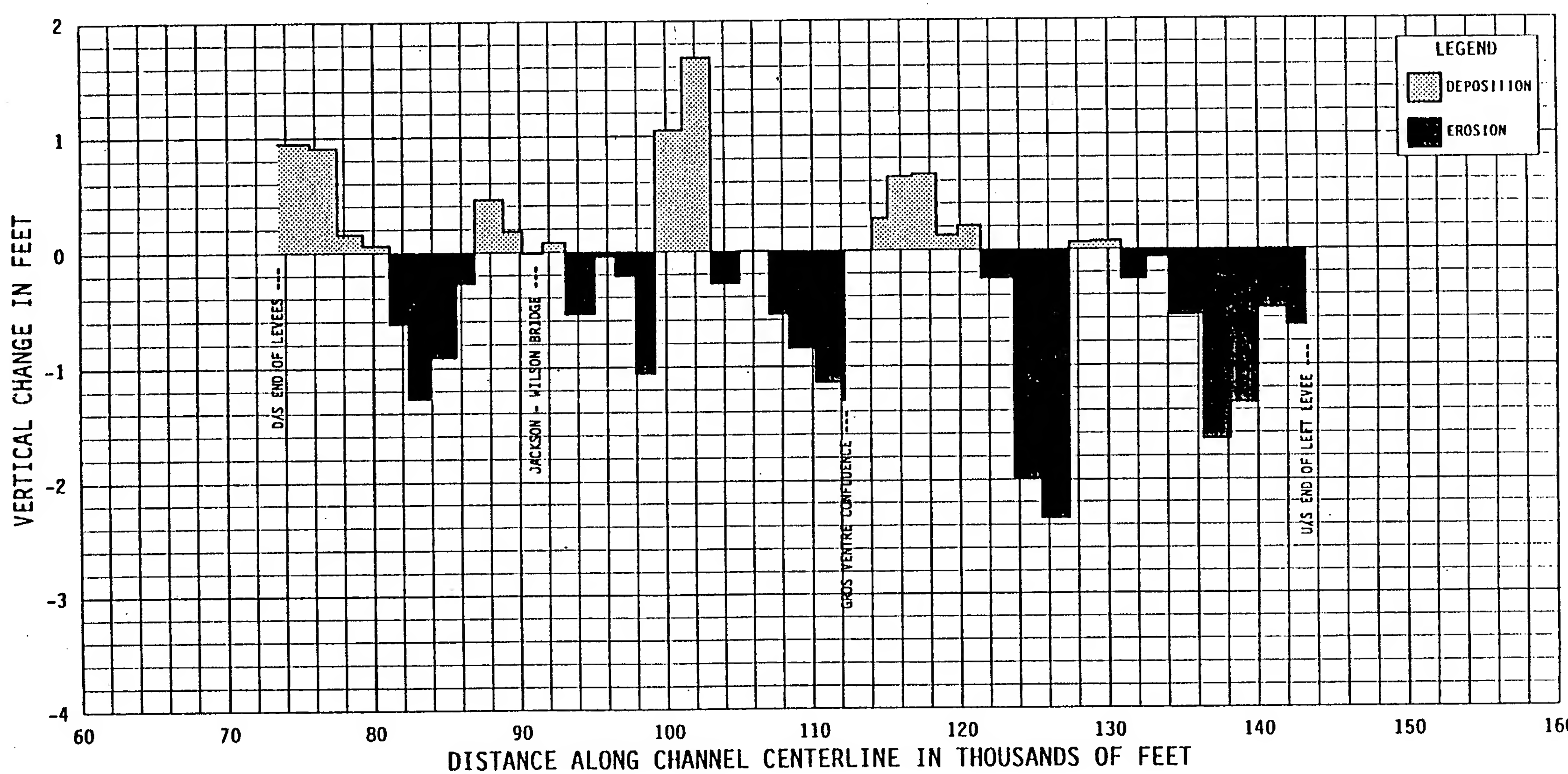
SNAKE RIVER NEAR JACKSON HOLE, WYOMING

AVERAGE VERTICAL CHANNEL BED CHANGE 1967 TO 1973

U.S. ARMY CORPS OF ENGINEERS

WALLA WALLA DISTRICT - HYDROLOGY BRANCH

DESIGNED BY:	DRAWN BY:	DATE
L. CUNNINGHAM	G. HARDIN	20 AUGUST 1992



NOTES:

1. VERTICAL CHANGE IN FEET WAS CALCULATED BY DIVIDING THE VOLUME CHANGE BY THE SURFACE AREA OF THE CHANNEL BOUNDED BY THE LEVEES AND THE SEDIMENT RANGE LINES.
2. DISTANCE ALONG THE CHANNEL CENTERLINE ROUGHLY CORRESPONDS TO STATIONING ALONG THE RIGHT LEVEE IN DESIGN MEMORANDUM #1, NOVEMBER 1955.

SNAKE RIVER BASIN

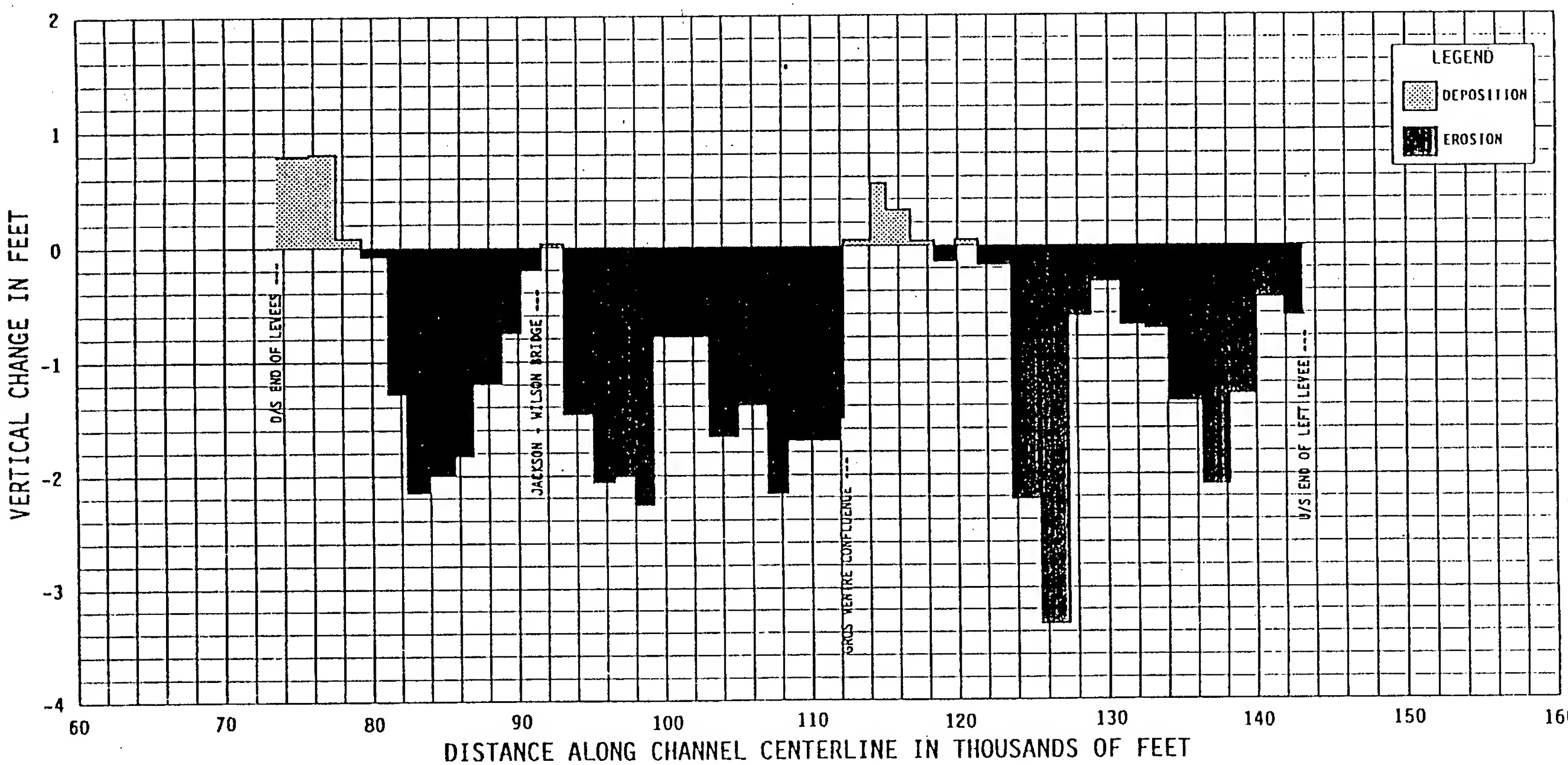
SNAKE RIVER NEAR JACKSON HOLE, WYOMING

AVERAGE VERTICAL CHANNEL BED CHANGE 1973 TO 1988

U.S. ARMY CORPS OF ENGINEERS

WALLA WALLA DISTRICT - HYDROLOGY BRANCH

DESIGNED BY:	DRAWN BY:	DATE
L. CUNNINGHAM	G. HARDIN	20 AUGUST 1992



NOTES:

1. VERTICAL CHANGE IN FEET WAS CALCULATED BY DIVIDING THE VOLUME CHANGE BY THE SURFACE AREA OF THE CHANNEL BOUNDED BY THE LEVEES AND THE SEDIMENT RANGE LINES.
2. DISTANCE ALONG THE CHANNEL CENTERLINE ROUGHLY CORRESPONDS TO STATIONING ALONG THE RIGHT LEVEE IN DESIGN MEMORANDUM #1, NOVEMBER 1955.

SNAKE RIVER BASIN

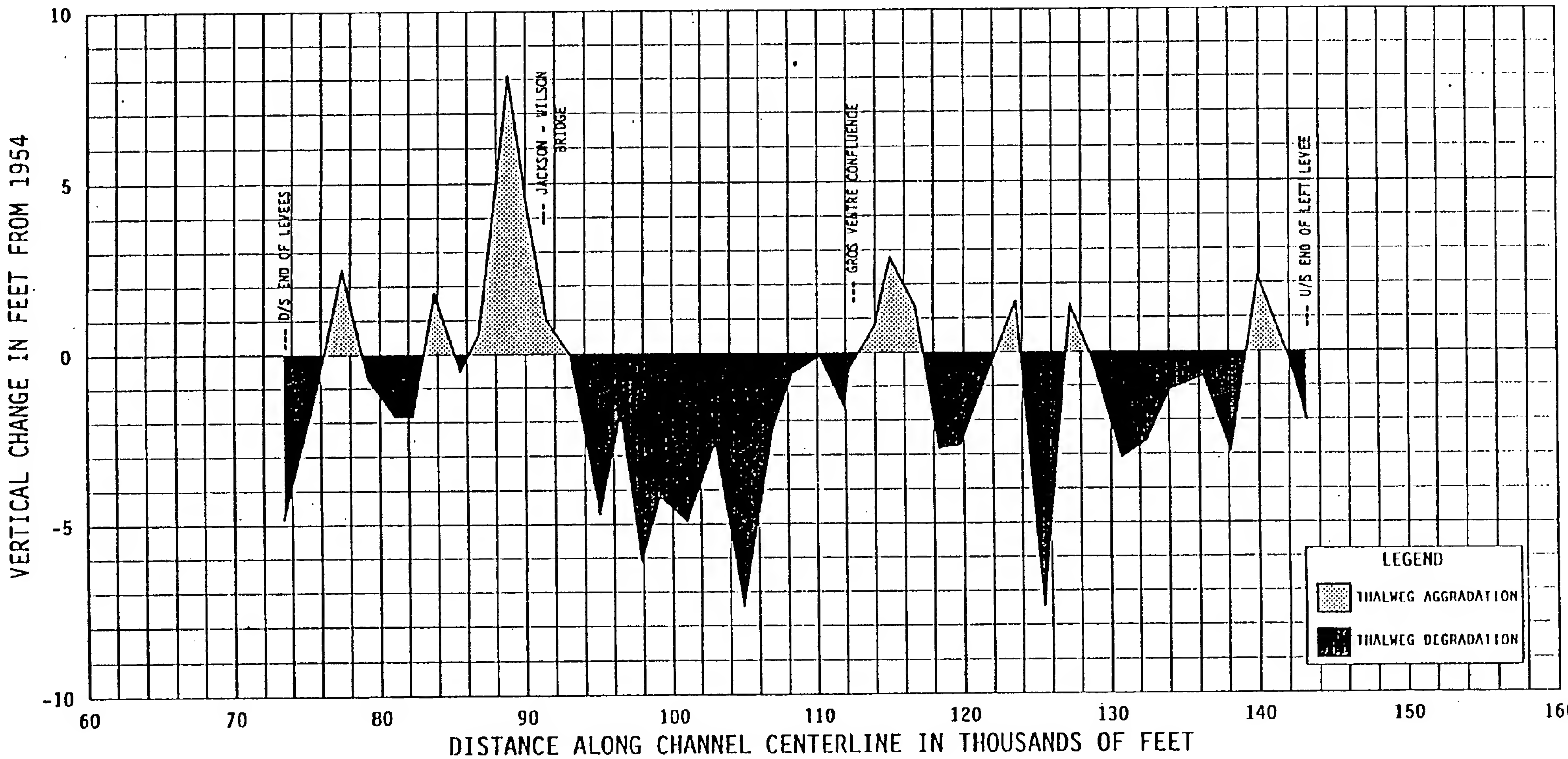
SNAKE RIVER NEAR JACKSON HOLE, WYOMING

AVERAGE VERTICAL CHANNEL BED CHANGE 1954 TO 1988

U.S. ARMY CORPS OF ENGINEERS

WALLA WALLA DISTRICT - HYDROLOGY BRANCH

DESIGNED BY:	DRAWN BY:	DATE
L. CUNNINGHAM	G. HARDIN	20 AUGUST 1992



NOTES:

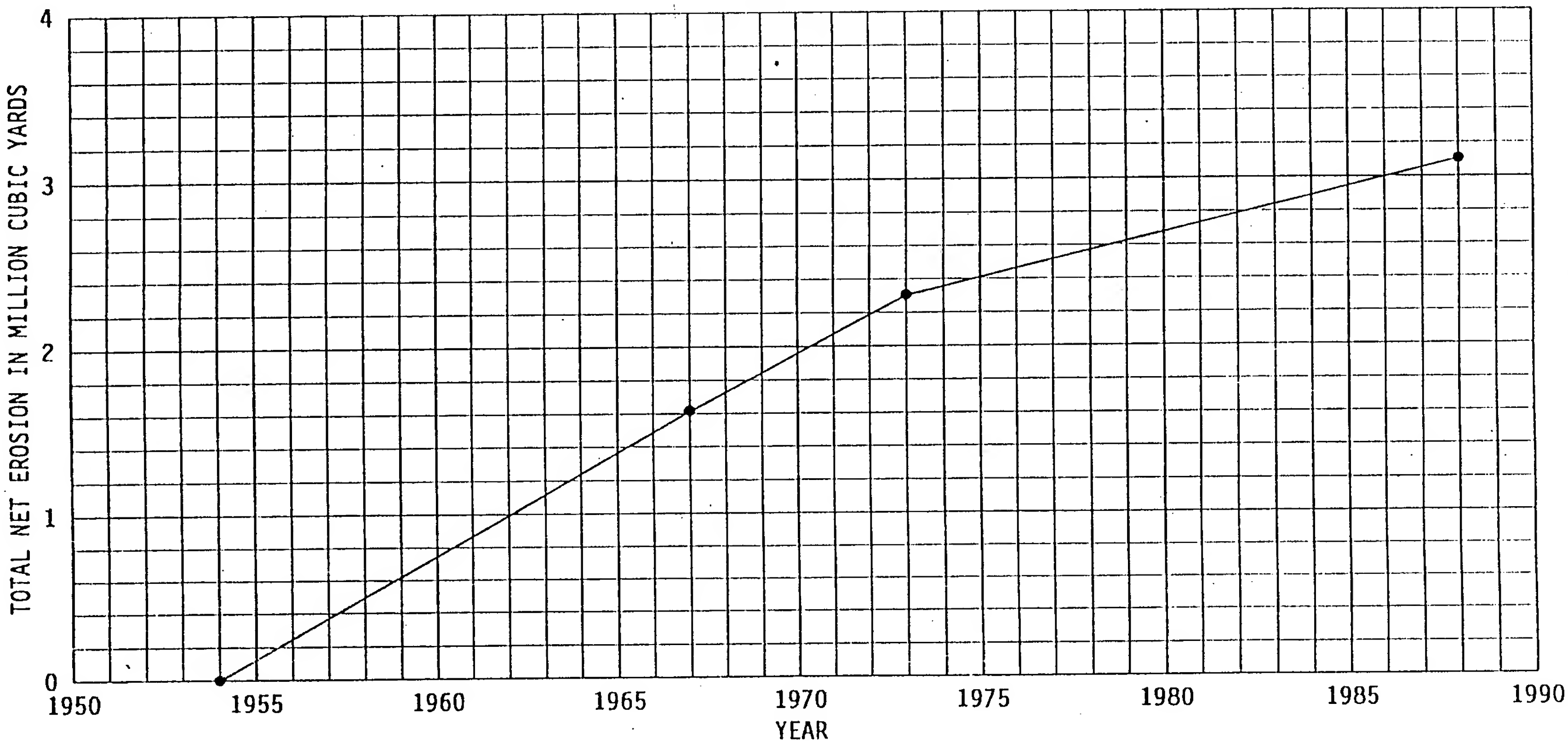
1. CHANNEL THALWEG DEGRADATION IS NEGATIVE; AGGRADATION IS POSITIVE.
2. CHANNEL THALWEG CHANGE IS SHOWN IN FEET ABOVE OR BELOW THE THALWEG SURVEYED IN 1954.
3. DISTANCE ALONG CENTERLINE ROUGHLY CORRESPONDS TO STATIONING ALONG RIGHT LEVEE IN DESIGN MEMORANDUM #1, NOVEMBER 1955.

SNAKE RIVER BASIN
SNAKE RIVER NEAR JACKSON HOLE, WYOMING

CHANGE IN THALWEG 1954 TO 1988

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT - HYDROLOGY BRANCH

DESIGNED BY:	DRAWN BY:	DATE
L. CUNNINGHAM	G. HARDIN	14 AUGUST 1992



NOTES:

1. THE ABOVE VOLUMES REPRESENT THE TOTAL NET EROSION IN THE FLOOD CONTROL PROJECT REACH (R.M. 147.1 TO 161.8) STARTING IN 1954.
2. CUMULATIVE EROSION VOLUMES WERE CALCULATED AT THE FOUR CIRCLED POINTS AND THEN CONNECTED WITH A STRAIGHT LINE. THE ACTUAL CONTINOUS RECORD WOULD FORM A CURVED LINE.

SNAKE RIVER BASIN

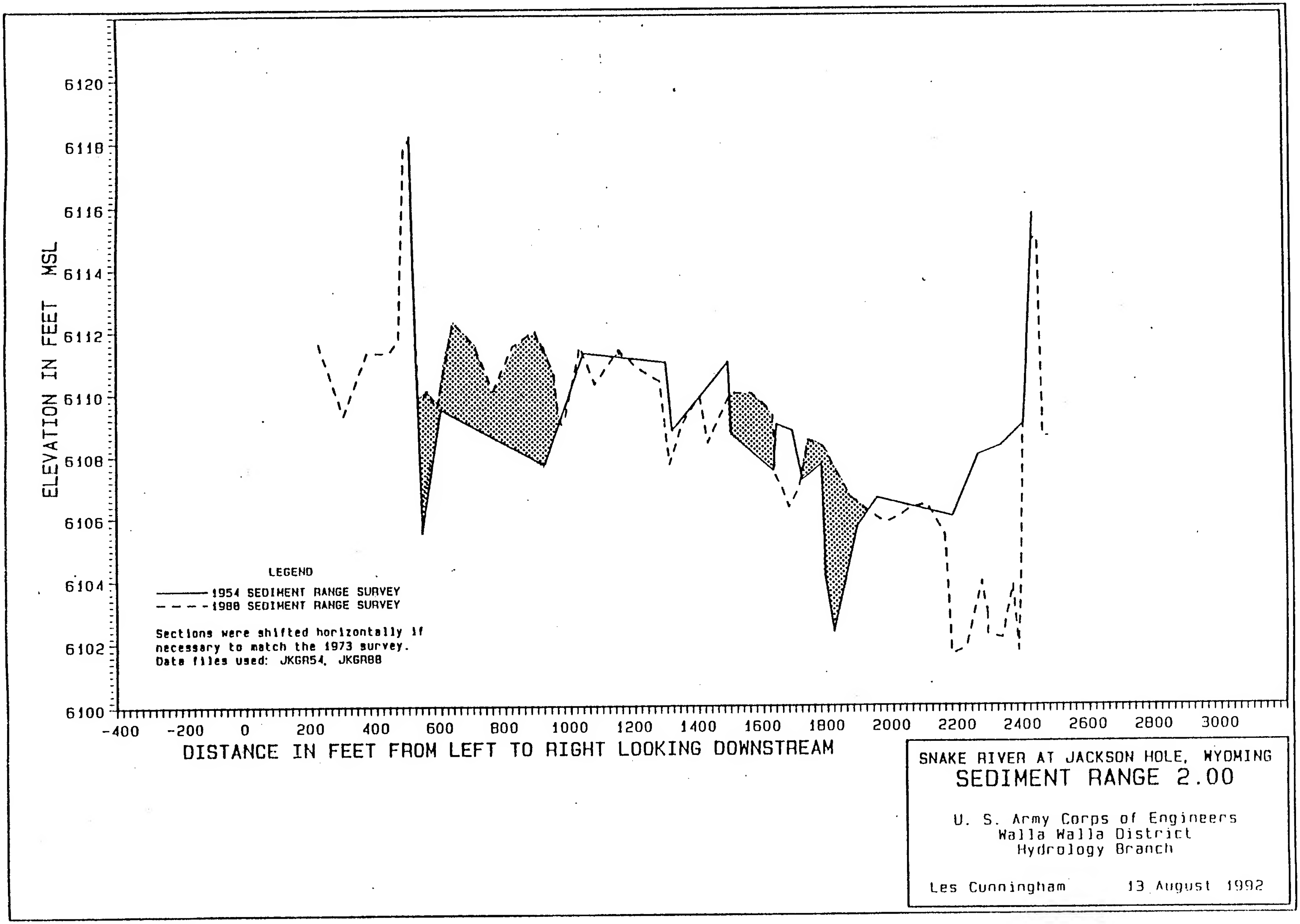
SNAKE RIVER NEAR JACKSON HOLE, WYOMING

LOSS OF MATERIAL FROM PROJECT REACH SINCE 1954

U.S. ARMY CORPS OF ENGINEERS

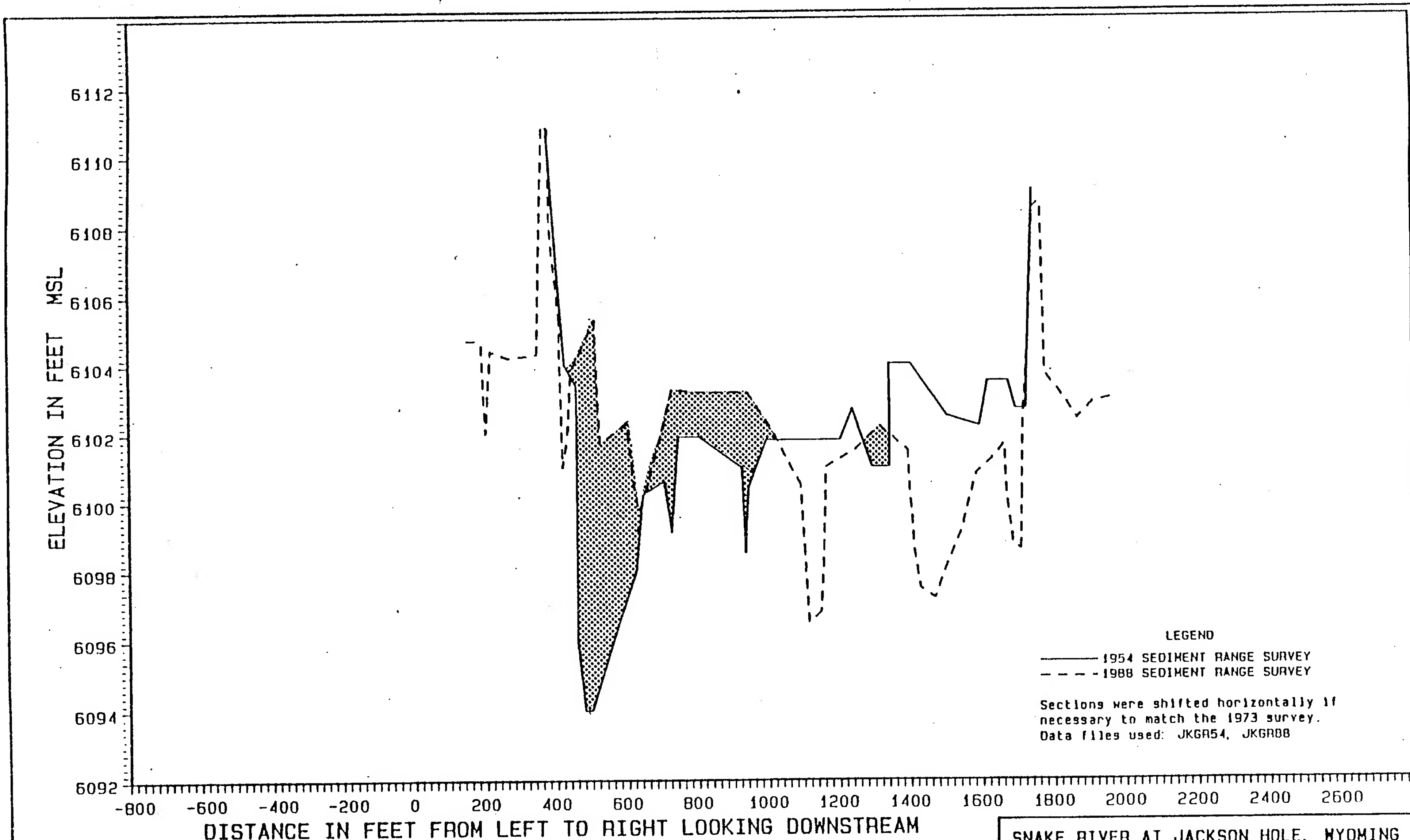
WALLA WALLA DISTRICT - HYDROLOGY BRANCH

DESIGNED BY:	DRAWN BY:	DATE
L. CUNNINGHAM	G. HARDIN	20 AUGUST 1992



SNAKE RIVER AT JACKSON HOLE, WYOMING
SEDIMENT RANGE 2.00
U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch
Les Cunningham
13 August 1992
ELEVATION IN FEET MSL
6100
6102
6104
6106
6108
6110
6112
6114
6116
6118
6120
DISTANCE IN FEET FROM LEFT TO RIGHT LOOKING DOWNSTREAM
-400
-200
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
LEGEND
1954 SEDIMENT RANGE SURVEY
1988 SEDIMENT RANGE SURVEY
Sections were shifted horizontally if necessary to match the 1973 survey.
Data files used: JKGR54, JKGR88

PLATE 22



SNAKE RIVER AT JACKSON HOLE, WYOMING

SEDIMENT RANGE 1.00

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 13 August 1992

PLATE 23

SITE 4

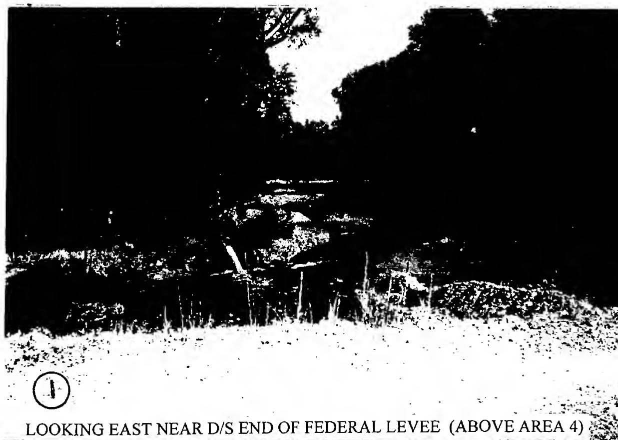
(18) (19) (19)

View of Snake River from bluff overlooking Site 4. Looking upstream.

(20) (21) (22)

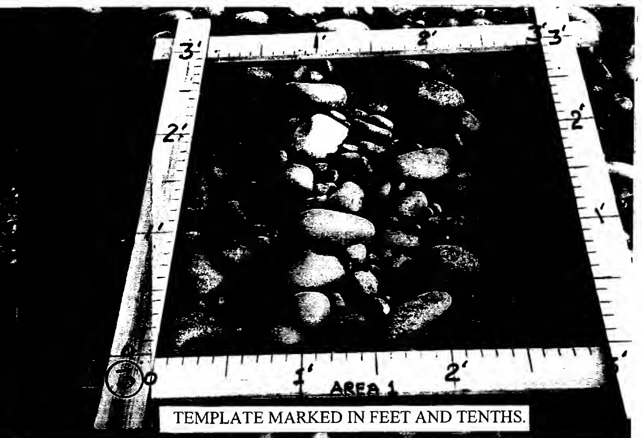
View of Snake River looking across and downstream from bluff.

PLATE 24

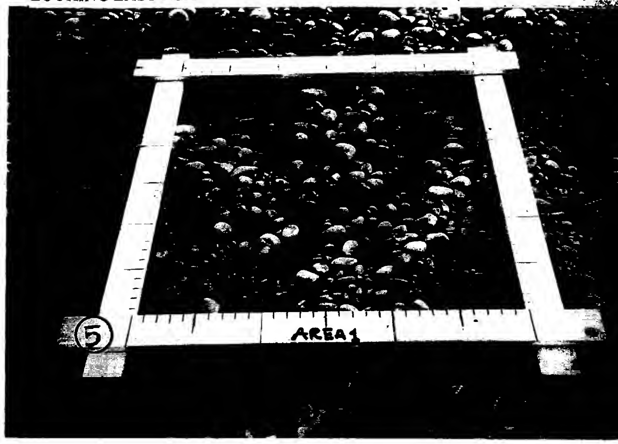


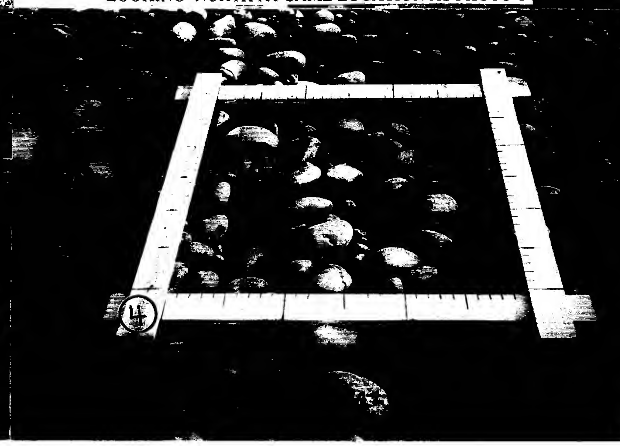
LOOKING EAST NEAR D/S END OF FEDERAL LEVEE (ABOVE AREA 4)

LOOKING NORTH AT SAME LOCATION AS PHOTO 1

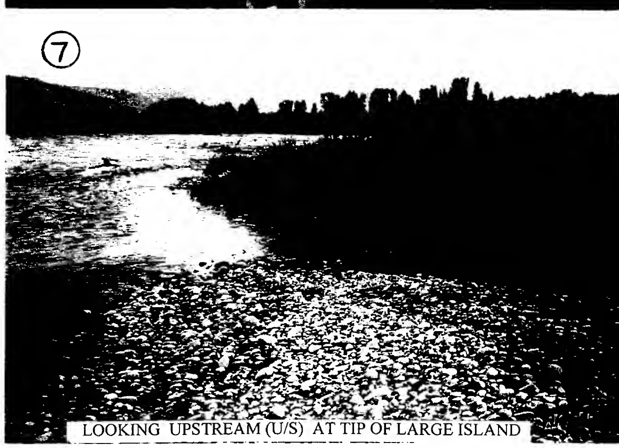


TEMPLATE MARKED IN FEET AND TENTHS.

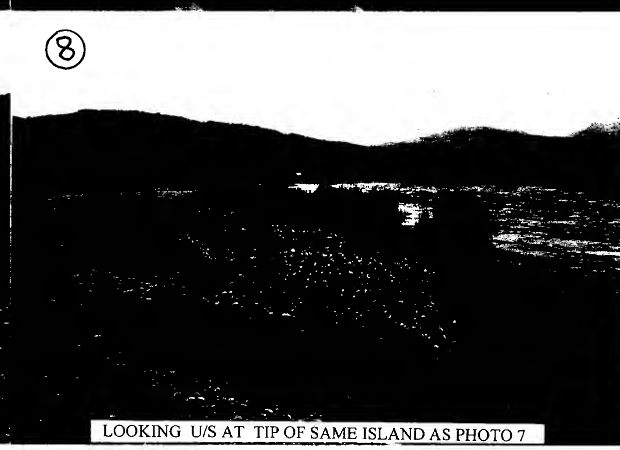




LOOKING D/S ON RIGHT SIDE OF LARGE, MID-CHANNEL ISLAND



LOOKING UPSTREAM (U/S) AT TIP OF LARGE ISLAND

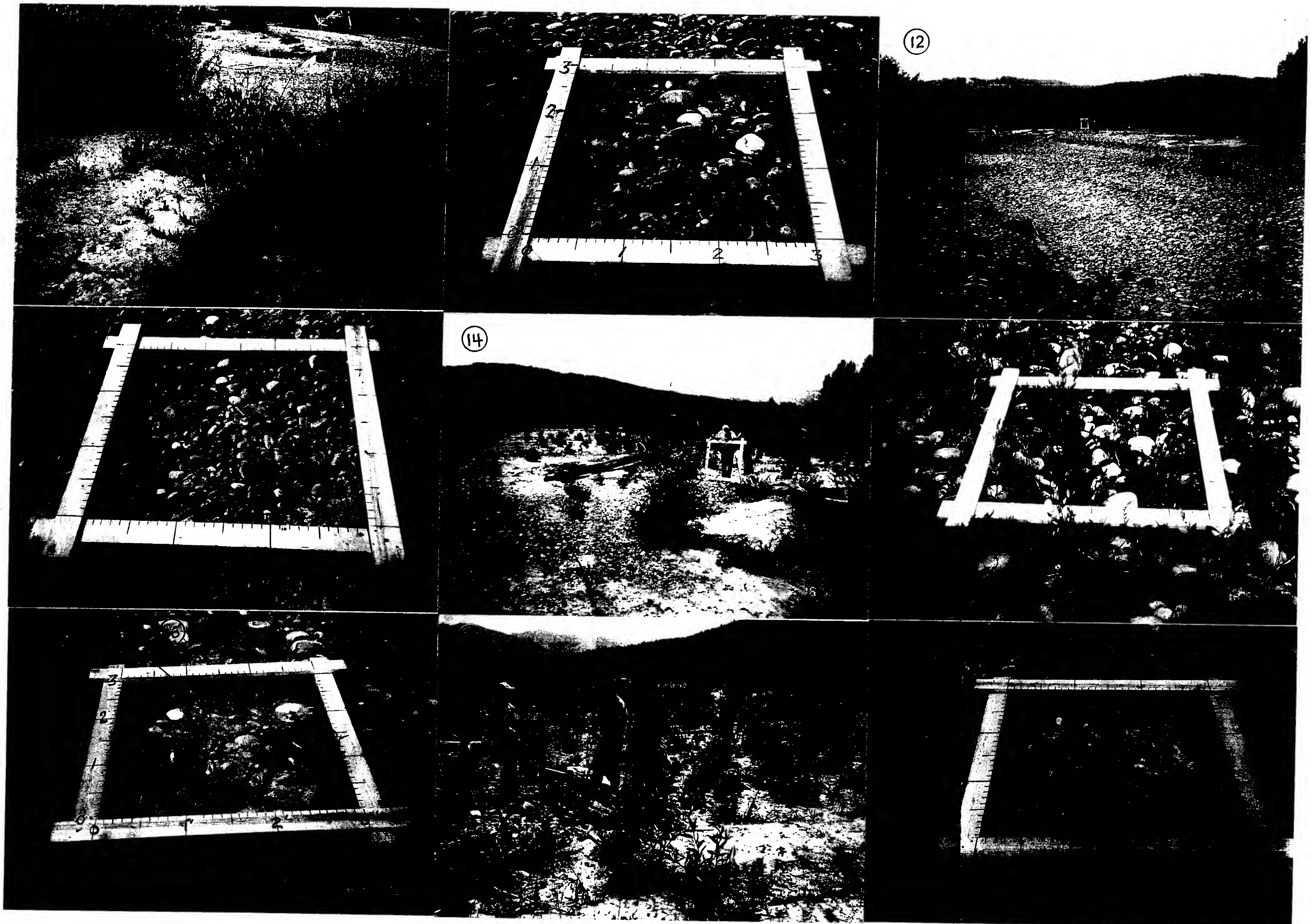


LOOKING U/S AT TIP OF SAME ISLAND AS PHOTO 7

LOOKING D/S FROM LEFT SIDE OF SAME ISLAND GROUP AS PHOTO 6

TYPICAL PHOTOS ILLUSTRATING DOCUMENTATION OF SEDIMENT SIZES

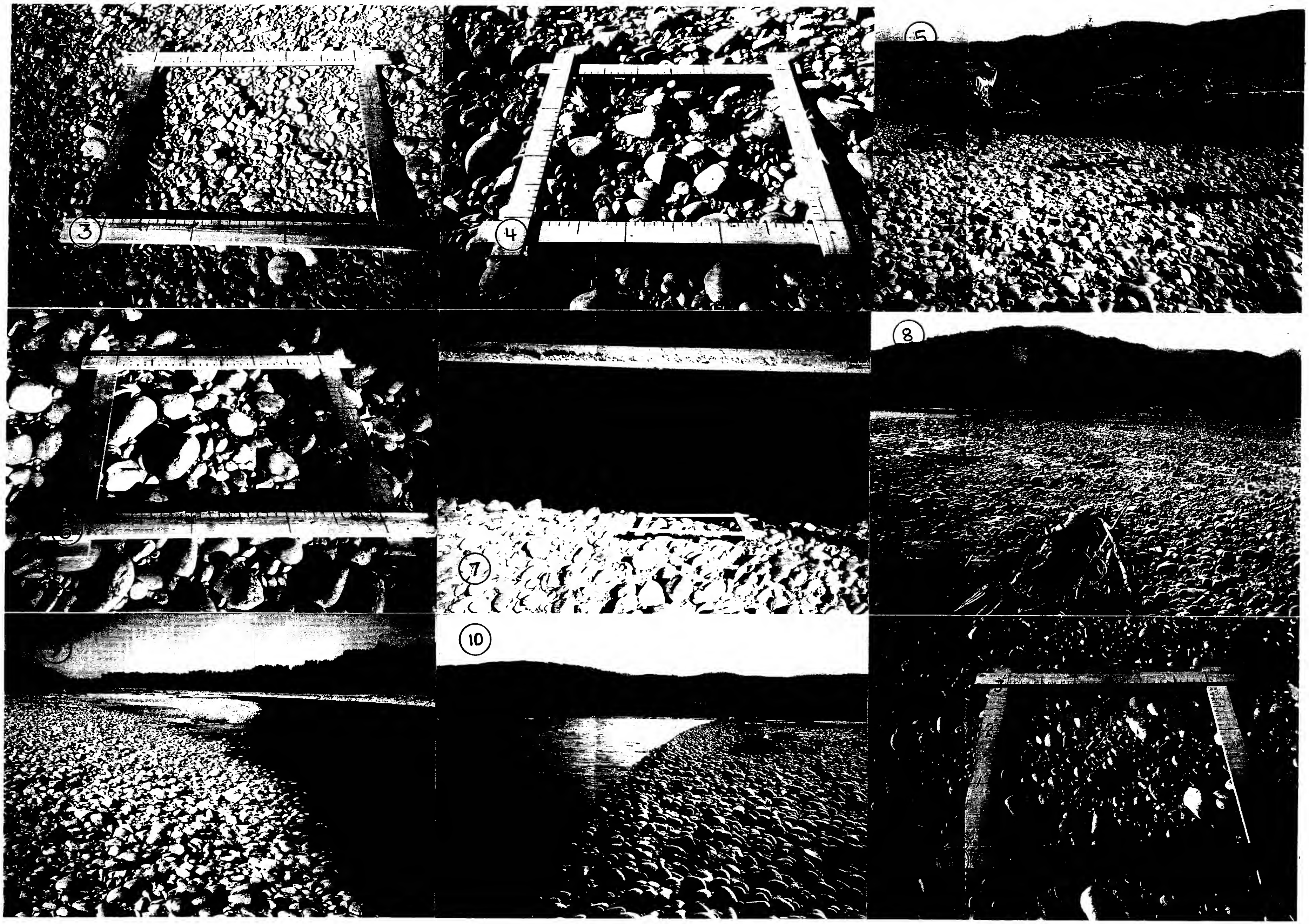
AREA 1 **PLATE 25**



TYPICAL PHOTOS ILLUSTRATING DOCUMENTATION OF SEDIMENT SIZES

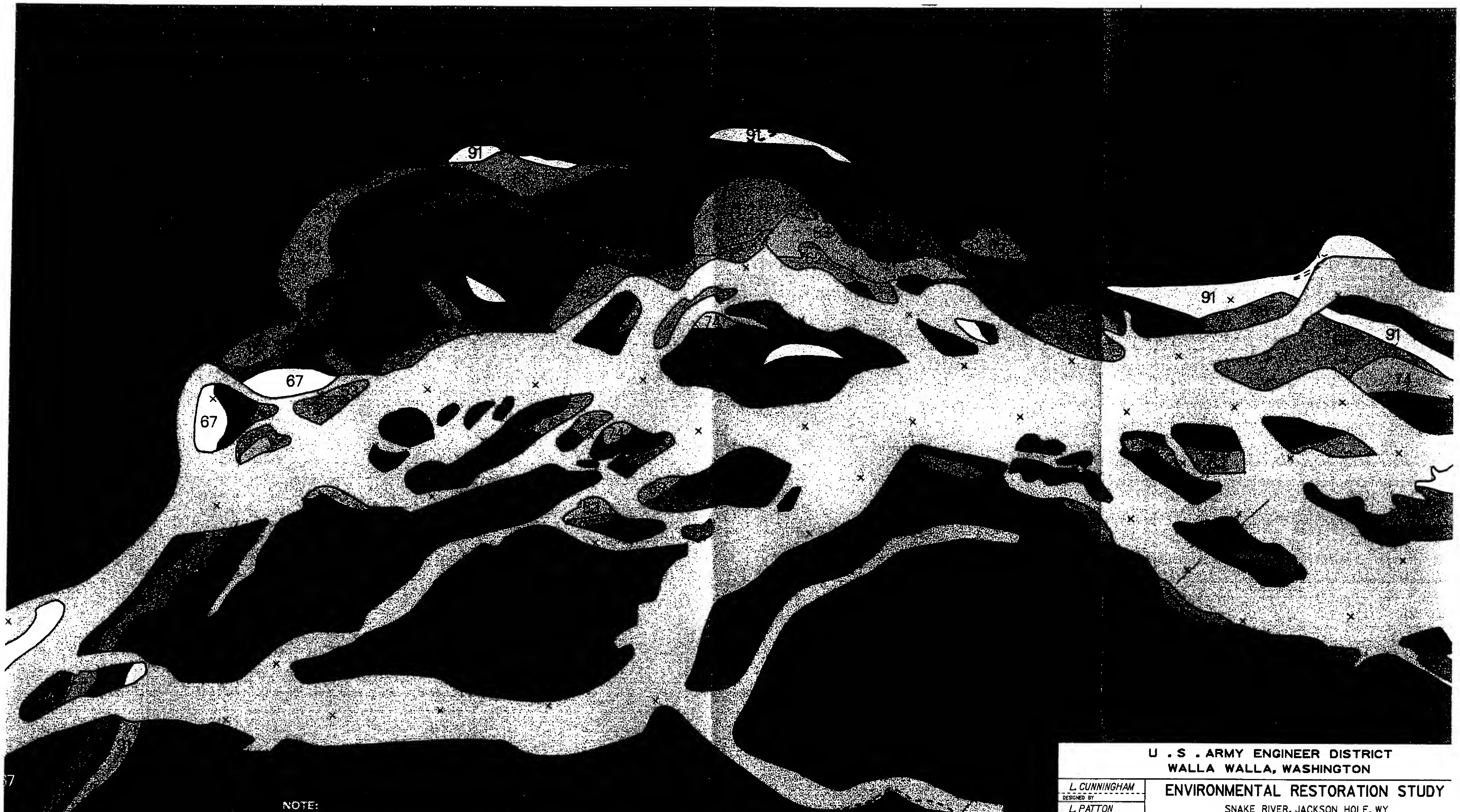
AREA 1

PLATE 26



TYPICAL PHOTOS ILLUSTRATING DOCUMENTATION OF SEDIMENT SIZES

AREA 4 PLATE 27



NOTE:

THE BLUE AREA REPRESENTS THE ACTIVE CHANNEL AS IT APPEARED IN 1945. THIS INCLUDED THE RIVER, GRAVEL BARS, AND ADJACENT AREAS WHICH WERE STRIPPED OF VEGETATION AT THE TIME.

EACH COLORED REGION REPRESENTS NEW EROSION IN AN AREA WHICH HAD NOT BEEN DISTURBED SINCE 1945. THE NUMBERS REPRESENT THE YEAR IN WHICH EROSION WAS NOTED ON AN AERIAL PHOTOGRAPH. DUE TO INCOMPLETE COVERAGE IN EARLIER AERIAL PHOTOS, SOME AREAS NEAR THE EDGES OF THE DRAWING MAY BE DATED TOO RECENT. REVEGETATED AREAS ARE NOT SHOWN.

GRID COORDINATES ARE BASED ON WYOMING WEST 1927 NORTH AMERICAN DATUM STATE PLANE COORDINATES.

COMPUTER AIDED DESIGN & DRAFTING
DESIGN FILENAME: /usr7/cad/jers/area1.dgn
PLOTTING TIME: 28-JAN-1998 13:48

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON

ENVIRONMENTAL RESTORATION STUDY
SNAKE RIVER, JACKSON HOLE, WY
SITE I
LOSS OF VEGETATED ISLAND AREAS
DUE TO BRAIDED CHANNEL CHANGES
BETWEEN 1945 AND 1997

DESIGNED BY: L. CUNNINGHAM
DRAWN BY (CADD DRAWN): L. PATTON
CHECKED BY:
SUPERVISED:
CHIEF:
SUBMITTED:
APPROVED: DATE:
CHIEF HYDROLOGY BRANCH
RECOMMENDED:
SCALE AS SHOWN | INV. NO.
PLATE NO.

VALUE ENGINEERING PAYS
CONT. NO.

PLATE 28

NOTE:

THE BLUE AREA REPRESENTS THE ACTIVE CHANNEL AS IT APPEARED IN 1945. THIS INCLUDED THE RIVER, GRAVEL BARS, AND ADJACENT AREAS WHICH WERE STRIPPED OF VEGETATION AT THE TIME.

EACH COLORED REGION REPRESENTS NEW EROSION IN AN AREA WHICH HAD NOT BEEN DISTURBED SINCE 1945. THE NUMBERS REPRESENT THE YEAR IN WHICH EROSION WAS NOTED ON AN AERIAL PHOTOGRAPH. DUE TO INCOMPLETE COVERAGE IN EARLIER AERIAL PHOTOS, SOME AREAS NEAR THE EDGES OF THE DRAWING MAY BE DATED TOO RECENT. REVEGETATED AREAS ARE NOT SHOWN.

GRID COORDINATES ARE BASED ON WYOMING WEST 1927 NORTH AMERICAN DATUM STATE PLANE COORDINATES.

COMPUTER AIDED DESIGN & DRAFTING

DESIGN FILENAME: /usr7/cad/jkrs/area4.dgn
PLOTTING TIME: 30-JAN-1998 08:51

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON

L. CUNNINGHAM — DESIGNED BY
E. ROGERS — DRAWN BY (CADD DRAWN)
N — CHECKED BY
SUPERVISED:
CHIEF S
SUBMITTED:
CHIEF HYDROLOGY BRANCH
RECOMMENDED:

ENVIRONMENTAL RESTORATION STUDY
SNAKE RIVER, JACKSON HOLE, WY
SITE 4
LOSS OF VEGETATED ISLAND AREAS
DUE TO BRAIDED CHANNEL CHANGES
BETWEEN 1945 AND 1997

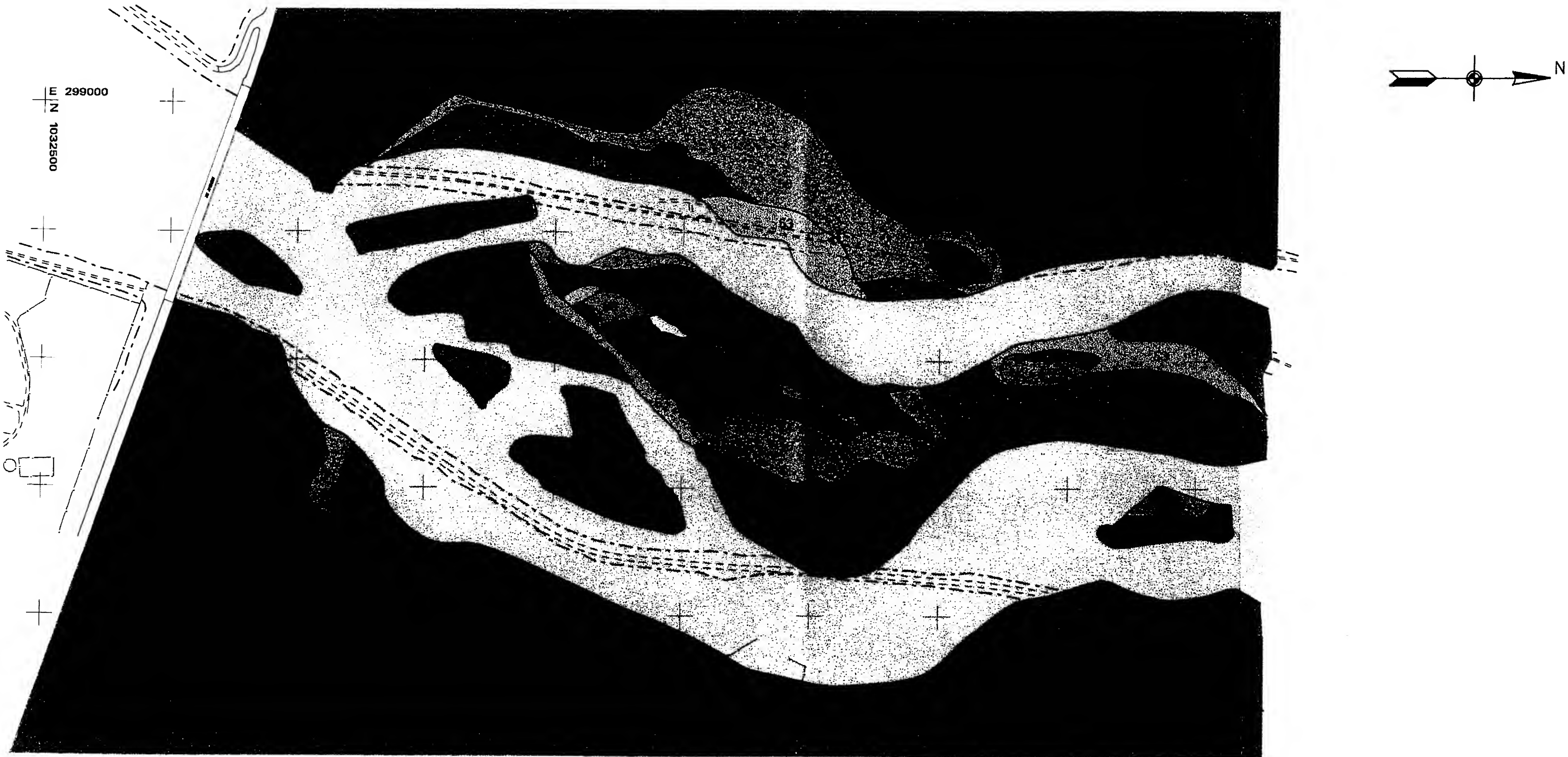
APPROVED: DATE

SCALE AS SHOWN | INV. NO.

PLATE NO.

CONT. NO.

PLATE 29



NOTE:

THE BLUE AREA REPRESENTS THE ACTIVE CHANNEL AS IT APPEARED IN 1944. THIS INCLUDED THE RIVER, GRAVEL BARS, AND ADJACENT AREAS WHICH WERE STRIPPED OF VEGETATION AT THE TIME.

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GRID COORDINATES ARE BASED ON WYOMING WEST 1927 NORTH AMERICAN DATUM STATE PLANE COORDINATES.

COMPUTER AIDED DESIGN & DRAFTING

DESIGN FILENAME: /usr7/cad/jers/area9.dgn

PLOTTING TIME: 26-JAN-1998 10:32

U . S . ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: L. CUNNINGHAM

DRAWN BY (CADD DRAWN): L. PATTON

CHECKED BY:

SUPERVISED:

CHIEF:

SUBMITTED:

CHIEF:

RECOMMENDED:

APPROVED:

DATE:

ENVIRONMENTAL RESTORATION STUDY

SNAKE RIVER, JACKSON HOLE, WY

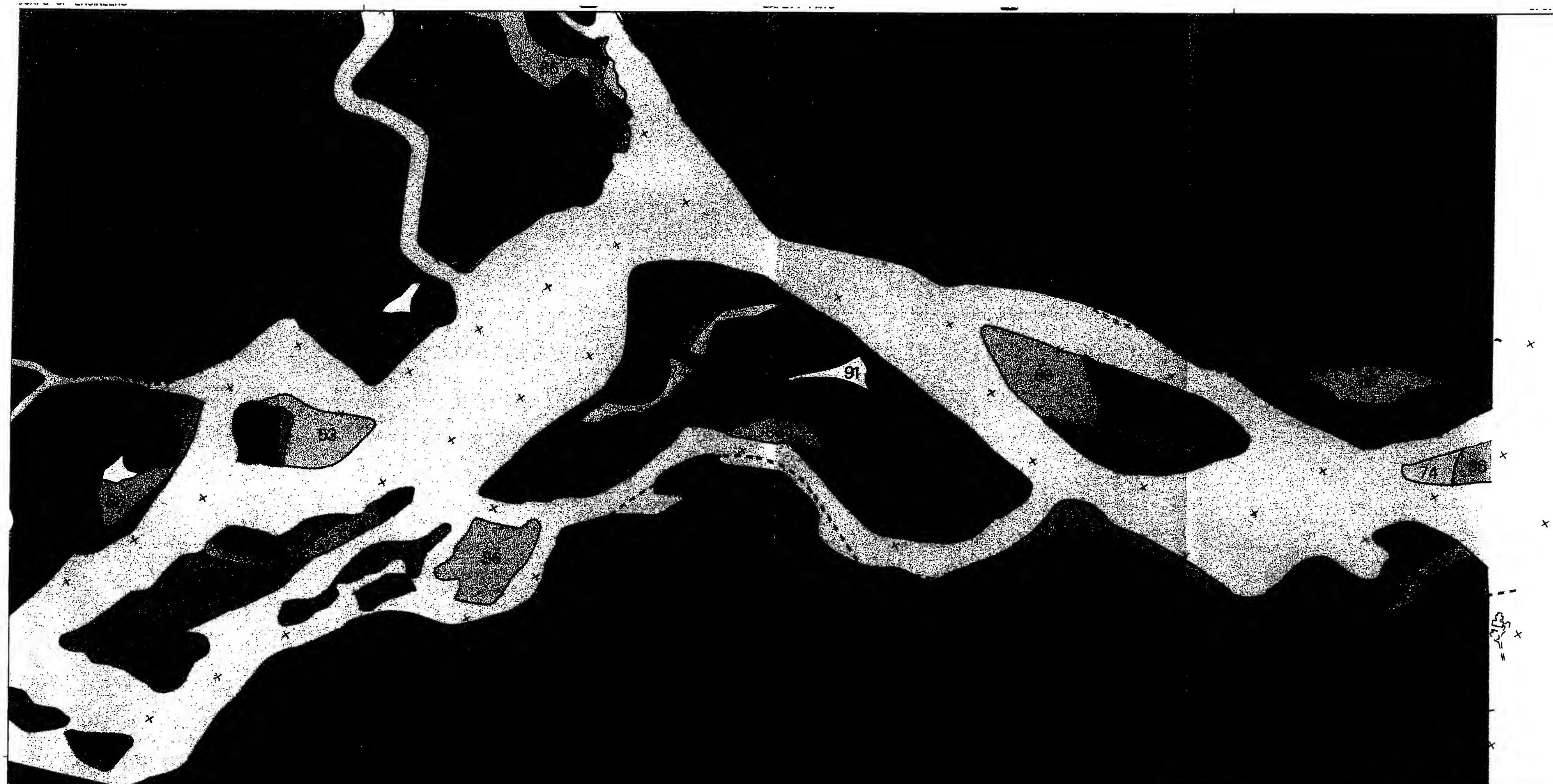
SITE 9

LOSS OF VEGETATED ISLAND AREAS DUE TO BRAIDED CHANNEL CHANGES BETWEEN 1945 AND 1997

SCALE AS SHOWN | INV. NO. | PLATE NO.

CONT. NO.

PLATE 30



NOTE:

THE BLUE AREA REPRESENTS THE ACTIVE CHANNEL AS IT APPEARED IN 1944. THIS INCLUDED THE RIVER, GRAVEL BARS, AND ADJACENT AREAS WHICH WERE STRIPPED OF VEGETATION AT THE TIME.

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GRID COORDINATES ARE BASED ON WYOMING WEST 1927 NORTH AMERICAN DATUM STATE PLANE COORDINATES.

COMPUTER AIDED DESIGN & DRAFTING

DESIGN FILENAME: /usr7/cad/jers/area10.dgn

PLOTTING TIME: 27-JAN-1998 08:56

U . S . ARMY ENGINEER DISTRICT
WALLA WALLA, WASHINGTON

L. CUNNINGHAM
DESIGNED BY
L. PATTON
DRAWN BY (CADD DRAWN)
CHECKED BY
SUPERVISED:
CHIEF S
SUBMITTED:
CHIEF D
RECOMMENDED:

ENVIRONMENTAL RESTORATION STUDY
SNAKE RIVER, JACKSON HOLE, WY
SITE 10

LOSS OF VEGETATED ISLAND AREAS
DUE TO BRAIDED CHANNEL CHANGES
BETWEEN 1945 AND 1997

APPROVED: DATE:

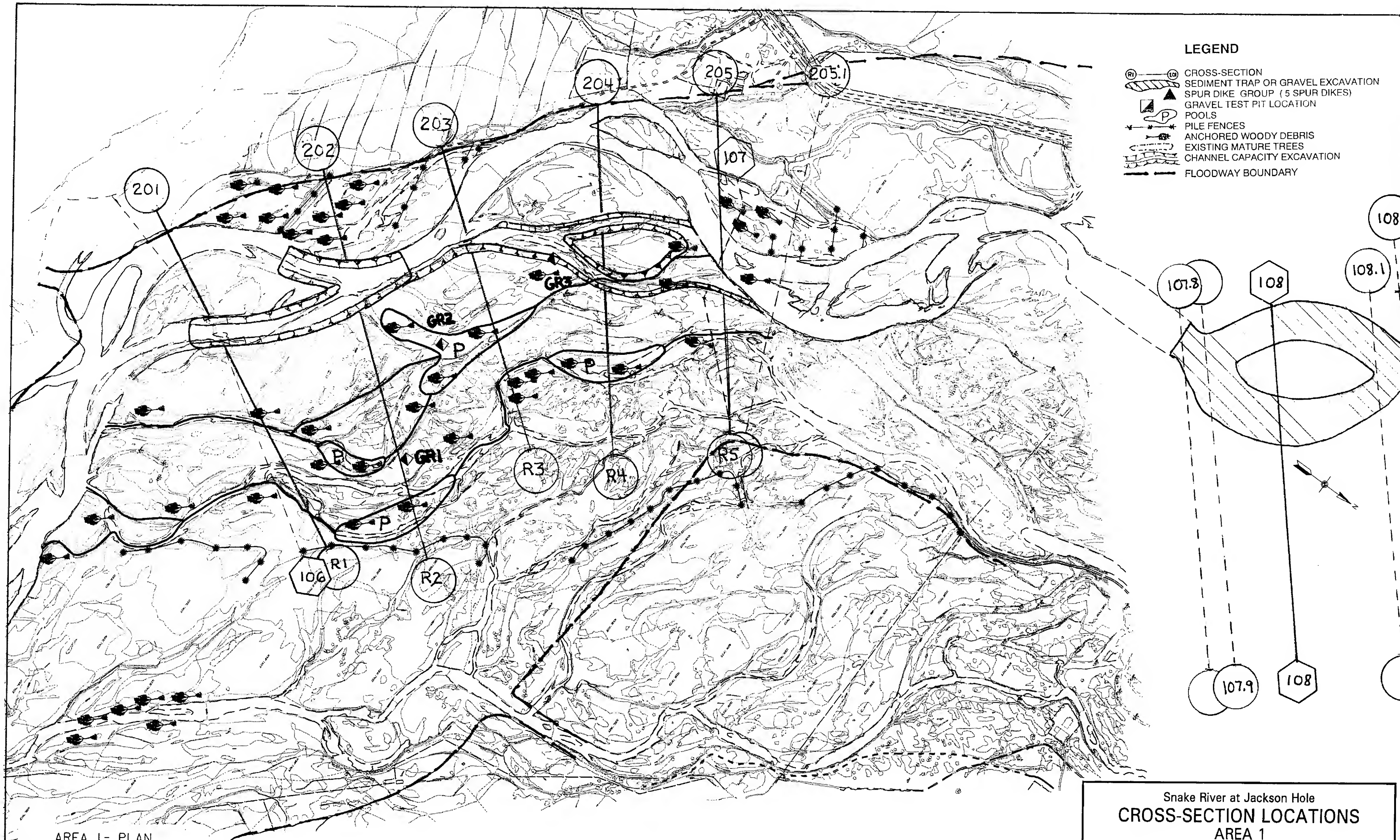
SCALE AS SHOWN | INV. NO.

PLATE NO.

VALUE ENGINEERING PAYS

CONT. NO.

PLATE 31



NOTE : Ranges R1-R5 were surveyed in the fall of 1996. Range 108 was surveyed in 1988. Ranges 107.8, 107.9, 108.1, and 108.2 were derived from 108 and were included to define the excavation area. Range 205.1 was developed from 1996 topography map with low-flow channel portion estimated. Topography for this map was based on 1996 photogrammetry.

Snake River at Jackson Hole

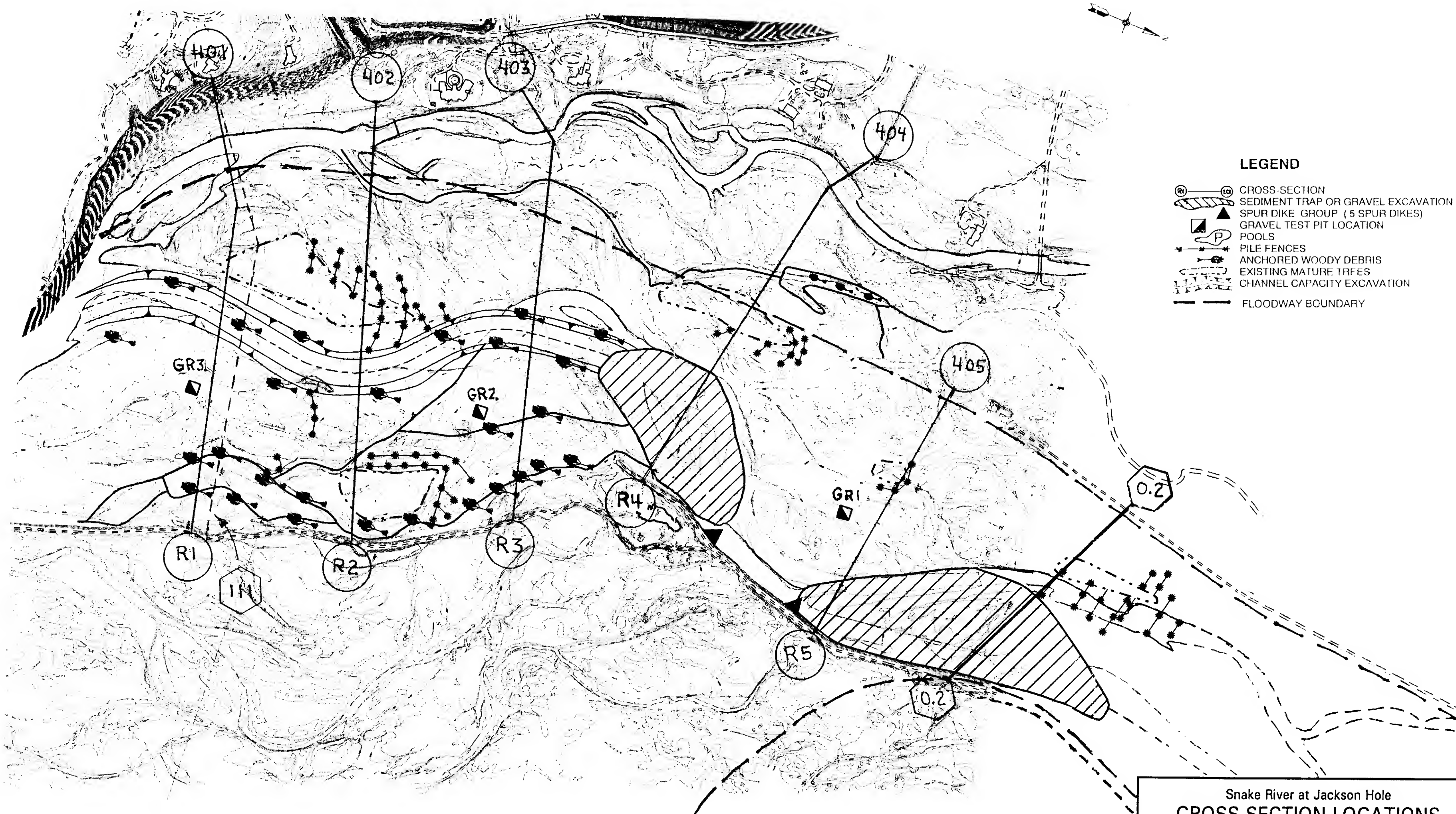
CROSS-SECTION LOCATIONS

AREA 1

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

30 September 1998

PLATE 32



AREA 4 - PLAN

SCALE IN FEET
300' 0 300'

NOTE: Ranges R1-R5 were surveyed in the fall of 1996. Range 111 and 0.2 were surveyed in 1988. Topography for this drawing was based on 1996 photogrammetry.

Snake River at Jackson Hole

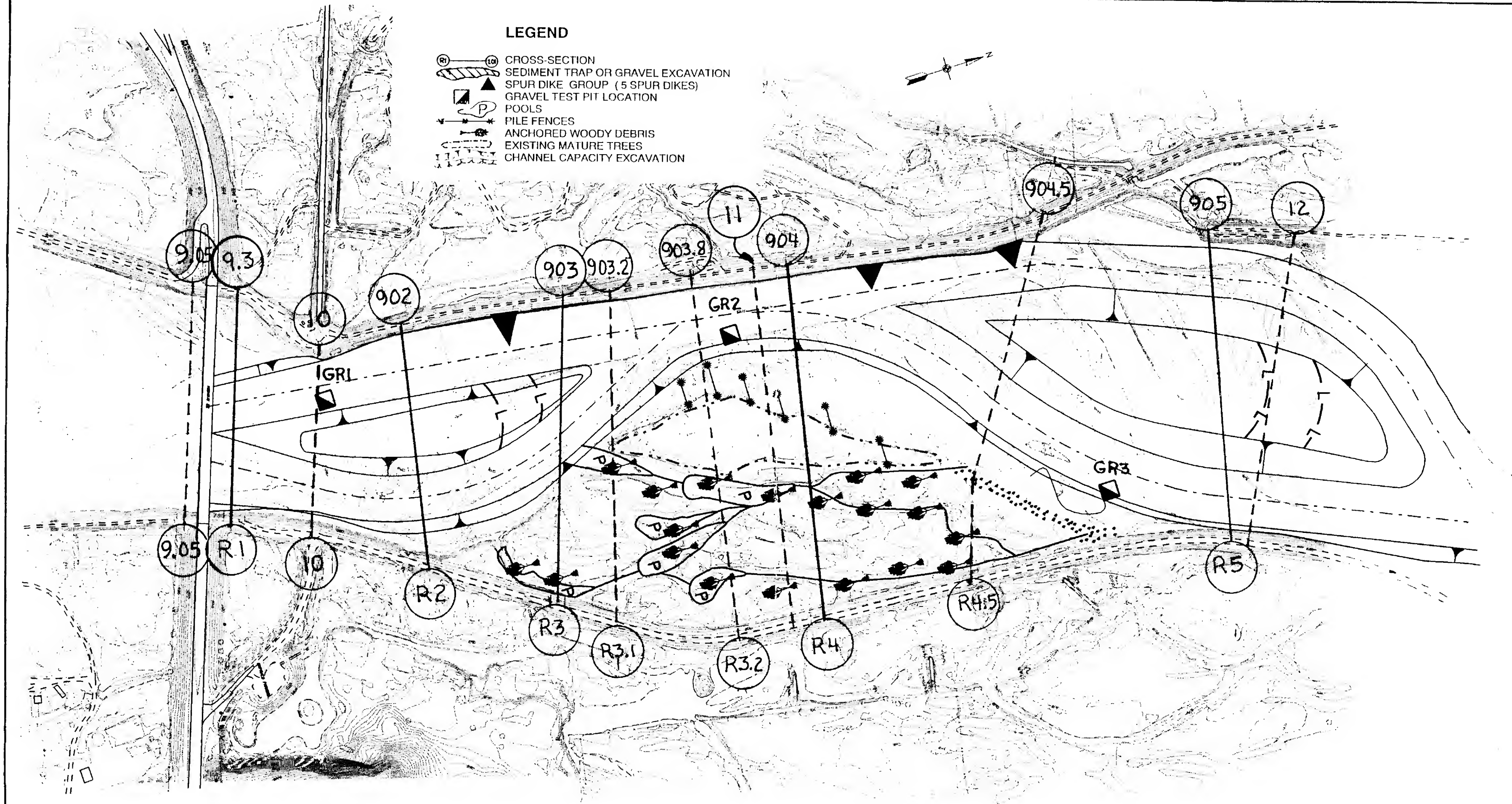
CROSS-SECTION LOCATIONS

AREA 4

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

30 September 1998

PLATE 33



NOTE: Ranges R1-R5 were surveyed in the fall of 1996. Range 9.05 was derived from 9..3. Ranges 10, R3.2, R3.8, R4.5, and 12 were developed from 1996 topography with estimated low-flow channel. Range 11 was derived from R4. Topography for this map was based on 1996 photogrammetry.

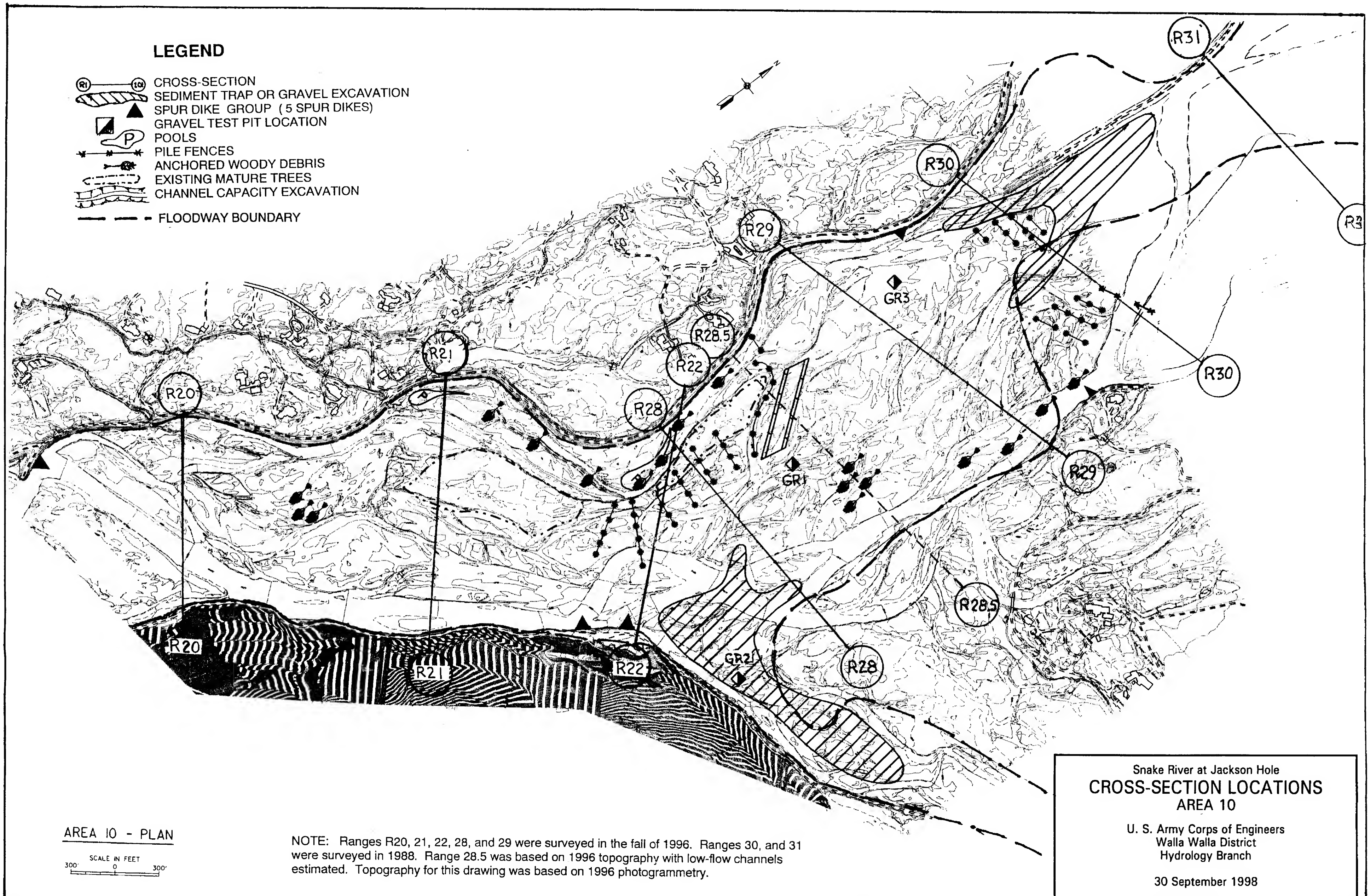
Snake River at Jackson Hole

CROSS-SECTION LOCATIONS
AREA 9

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

30 September 1998

PLATE 34



NOTE: Ranges R20, 21, 22, 28, and 29 were surveyed in the fall of 1996. Ranges 30, and 31 were surveyed in 1988. Range 28.5 was based on 1996 topography with low-flow channels estimated. Topography for this drawing was based on 1996 photogrammetry.

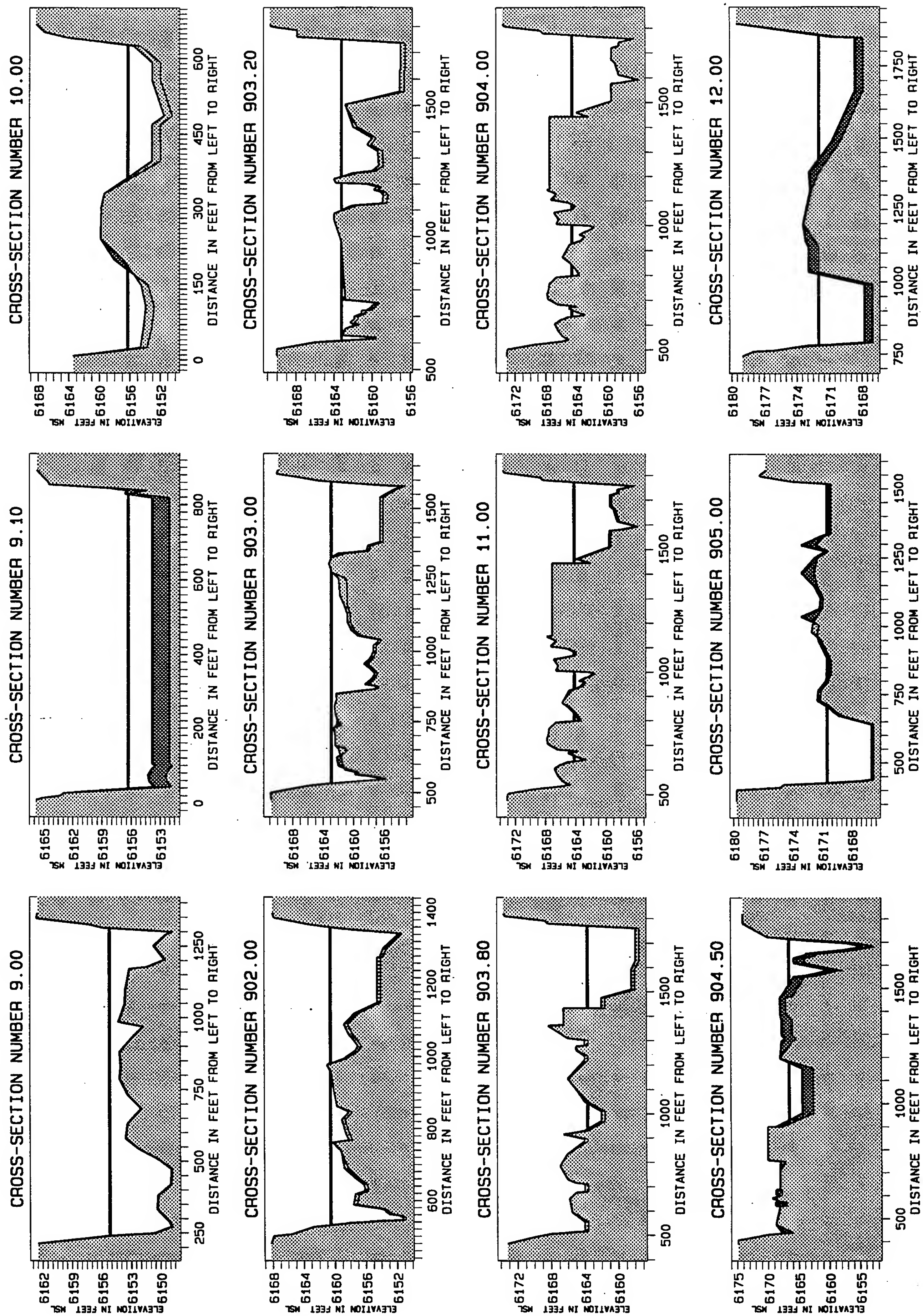
Snake River at Jackson Hole

CROSS-SECTION LOCATIONS
AREA 10

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

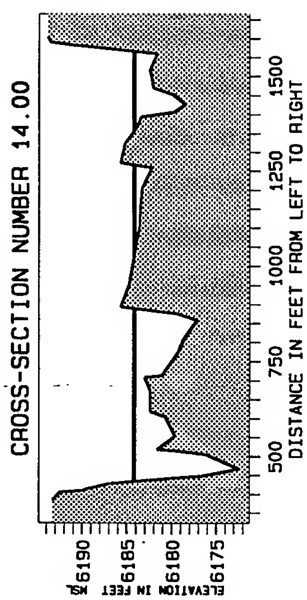
30 September 1998

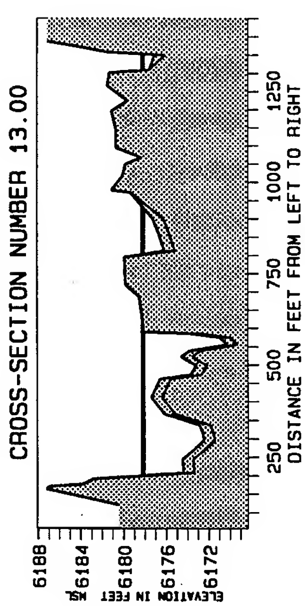
PLATE 35



Calculated Change in Cross-Sections: Area 9

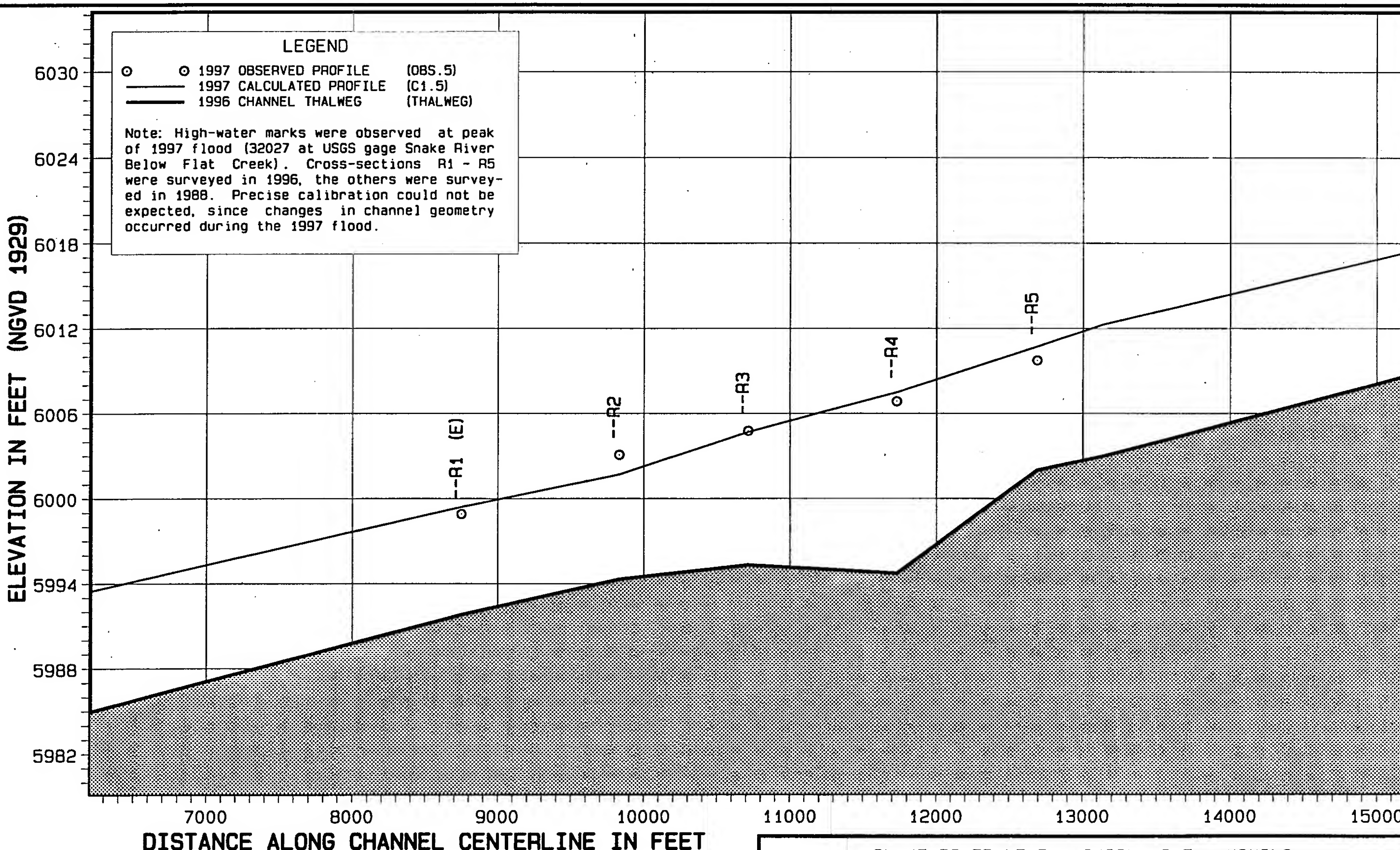
PLATE 36





Calculated Change in Cross-Sections: Area 9 continued

PLATE 37



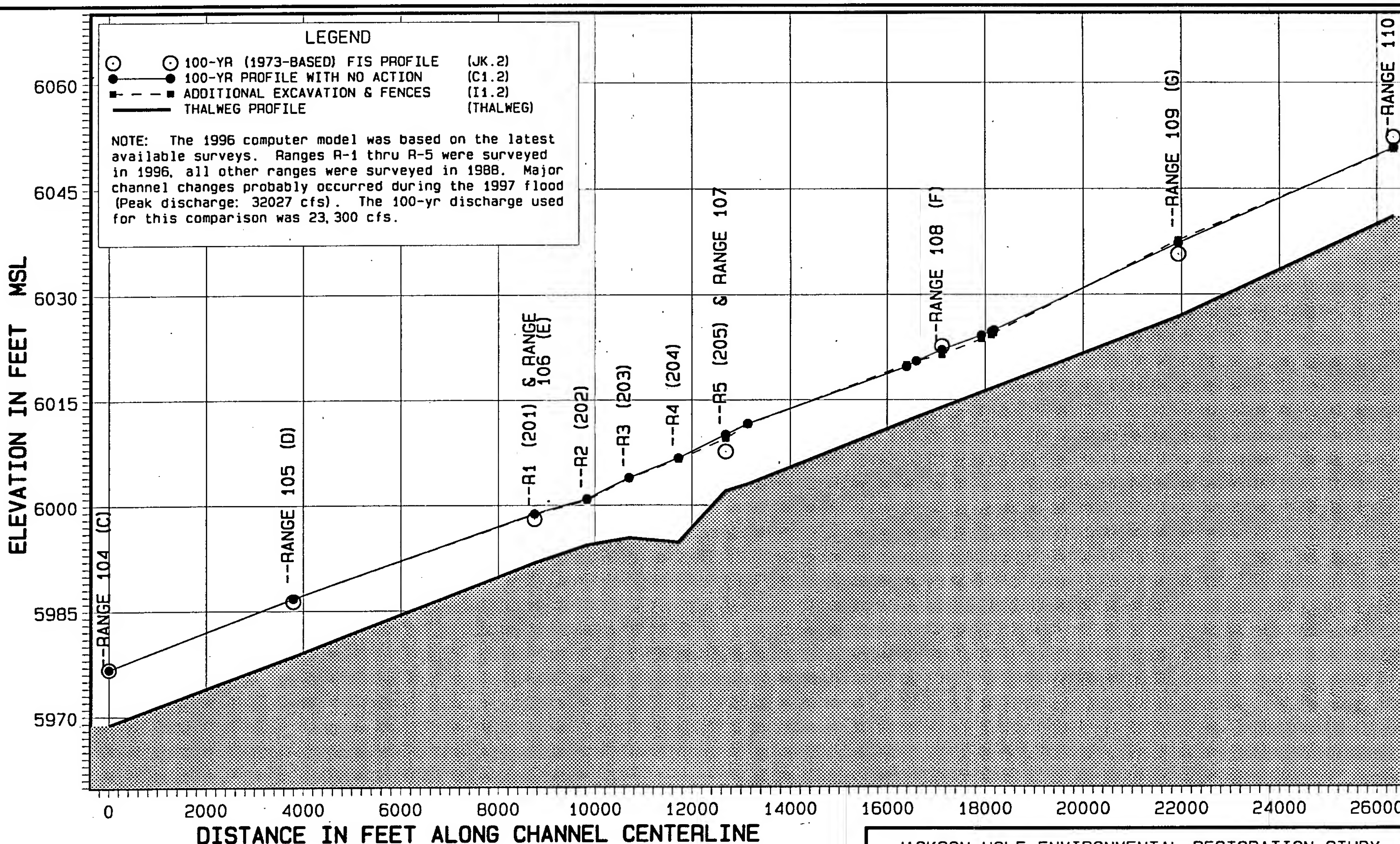
SNAKE RIVER NEAR JACKSON HOLE, WYOMING
AREA 1. JACKSON HOLE ENVIRONMENTAL RESTORATION STUDY

OBSERVED VS CALCULATED WATER-SURFACE PROFILES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

AUGUST 1998

PLATE A1-1



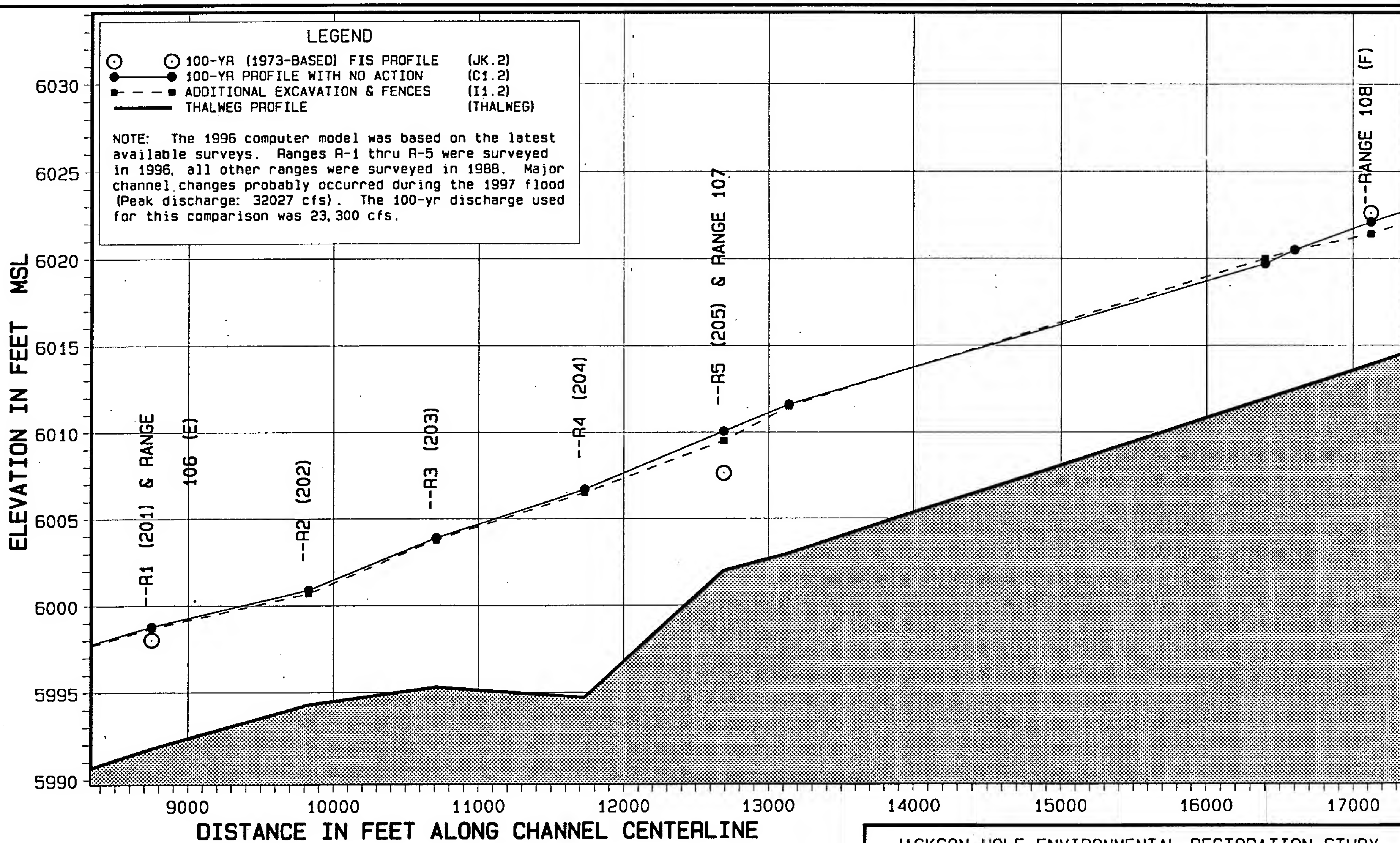
JACKSON HOLE ENVIRONMENTAL RESTORATION STUDY

AREA 1: 100-YEAR FLOOD PROFILES WITH AND WITHOUT RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

AUGUST 1998

PLATE A1-2

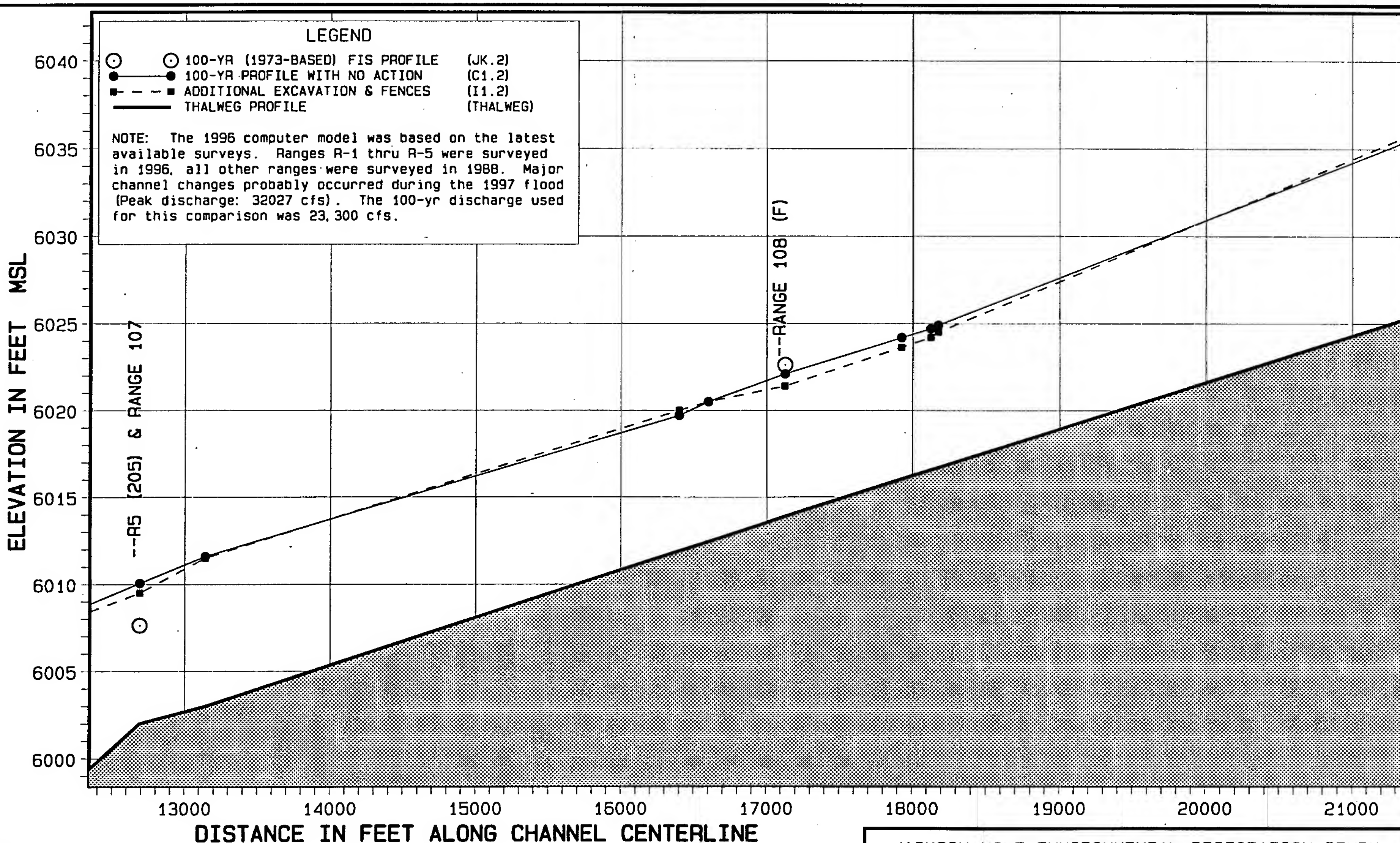


JACKSON HOLE ENVIRONMENTAL RESTORATION STUDY

AREA 1: 100-YEAR FLOOD PROFILES WITH AND WITHOUT RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

AUGUST 1998

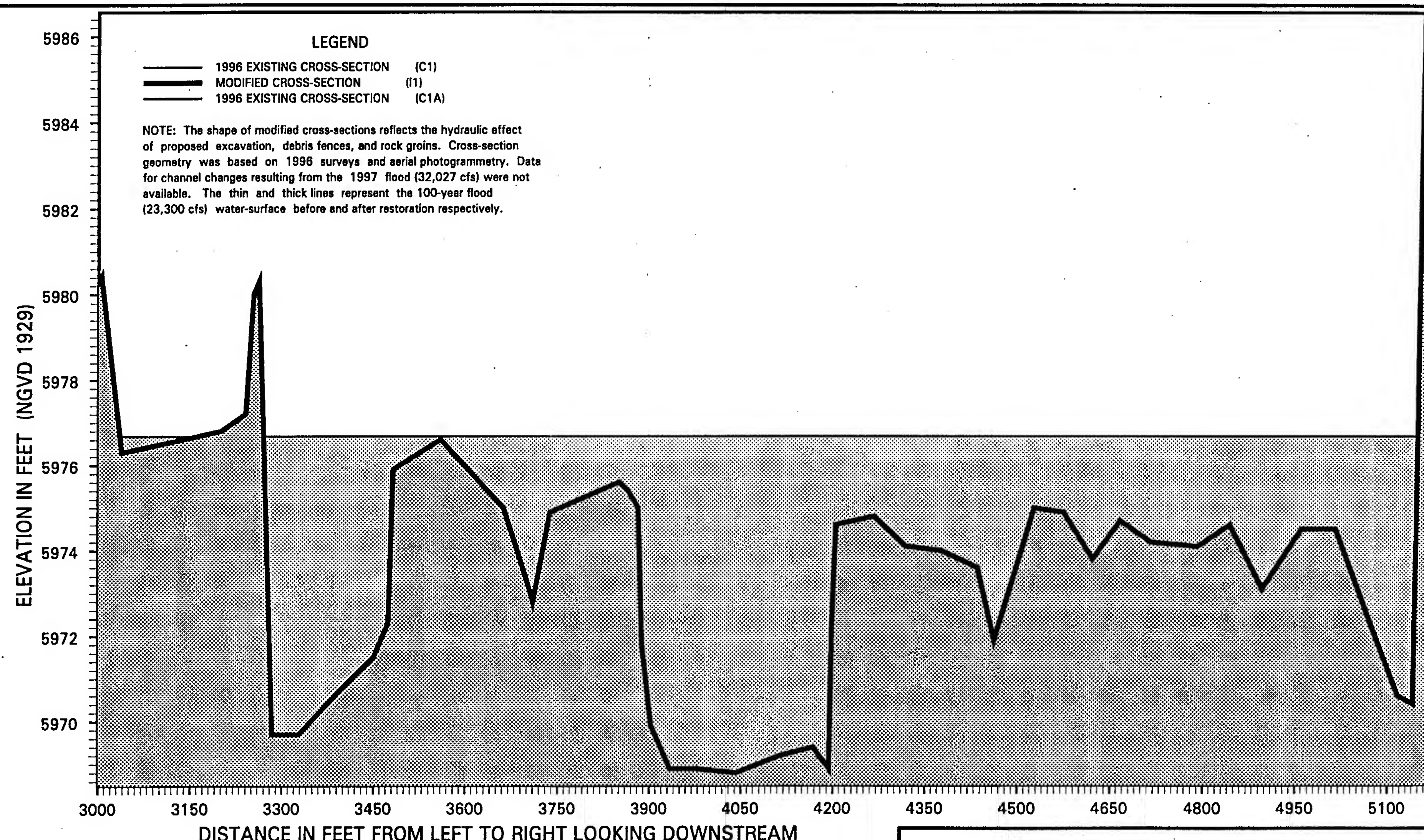


JACKSON HOLE ENVIRONMENTAL RESTORATION STUDY

AREA 1: 100-YEAR FLOOD PROFILES
WITH AND WITHOUT RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

AUGUST 1998

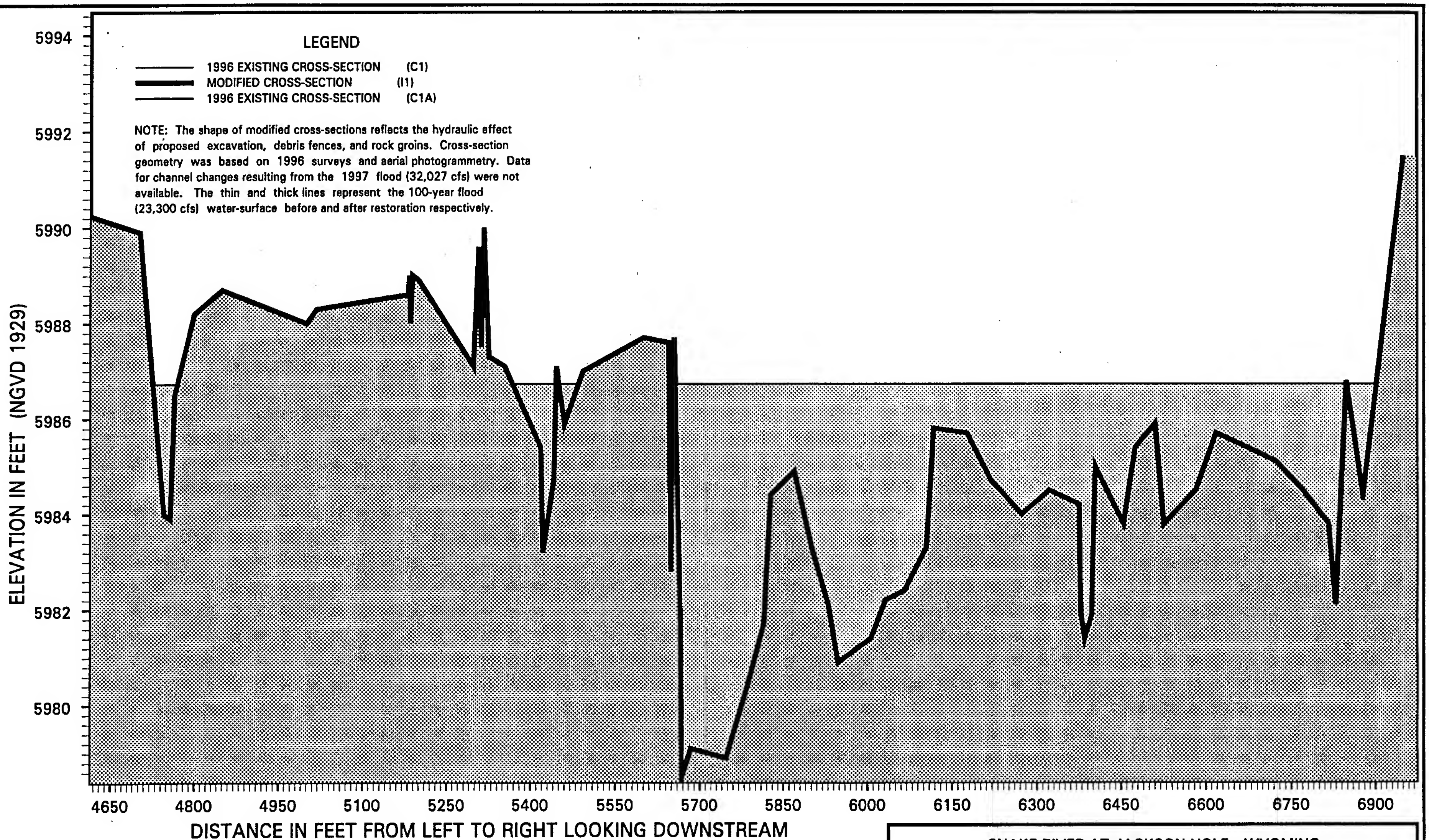


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 104.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998



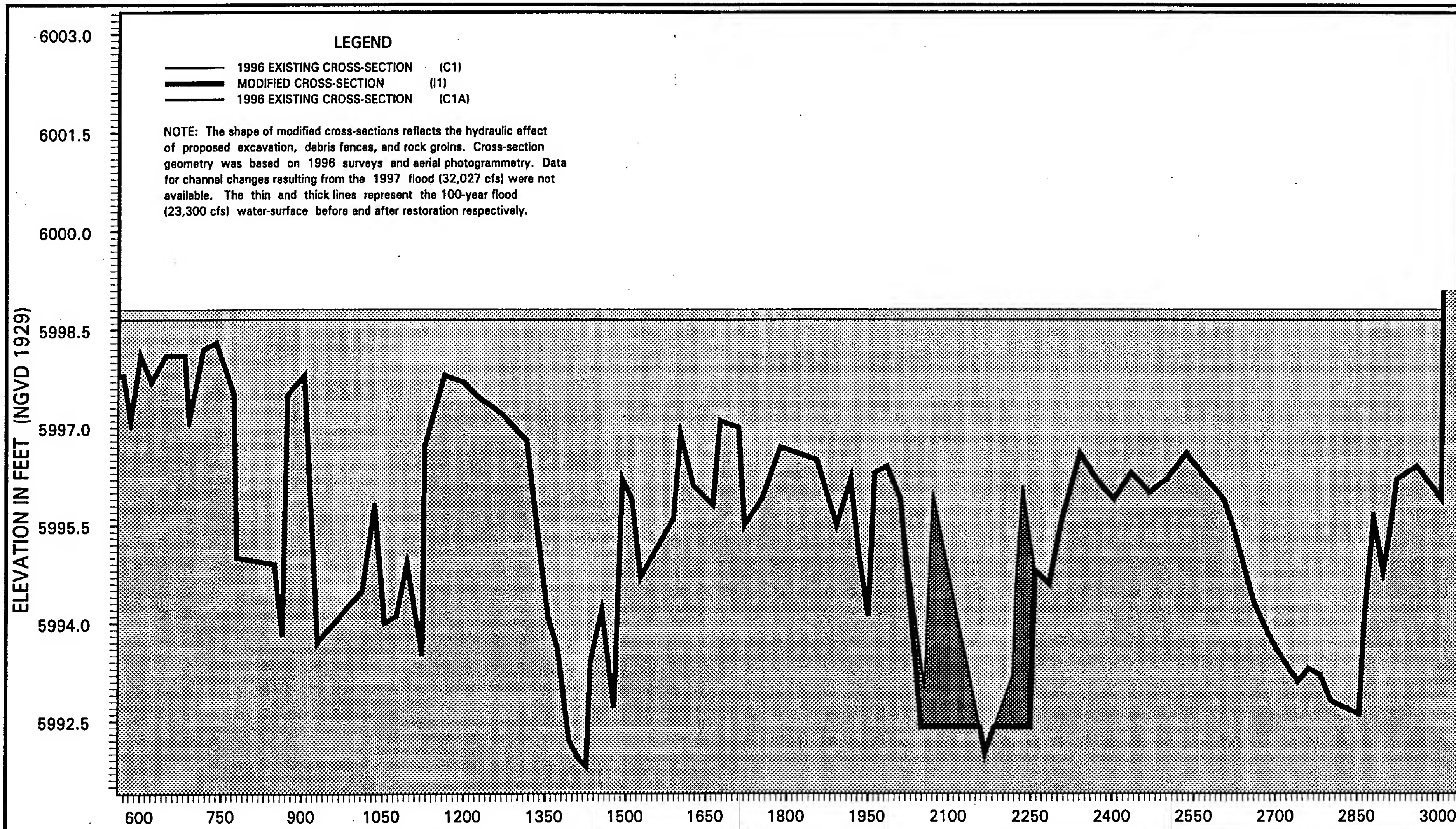
SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 105.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998

PLATE A1-6



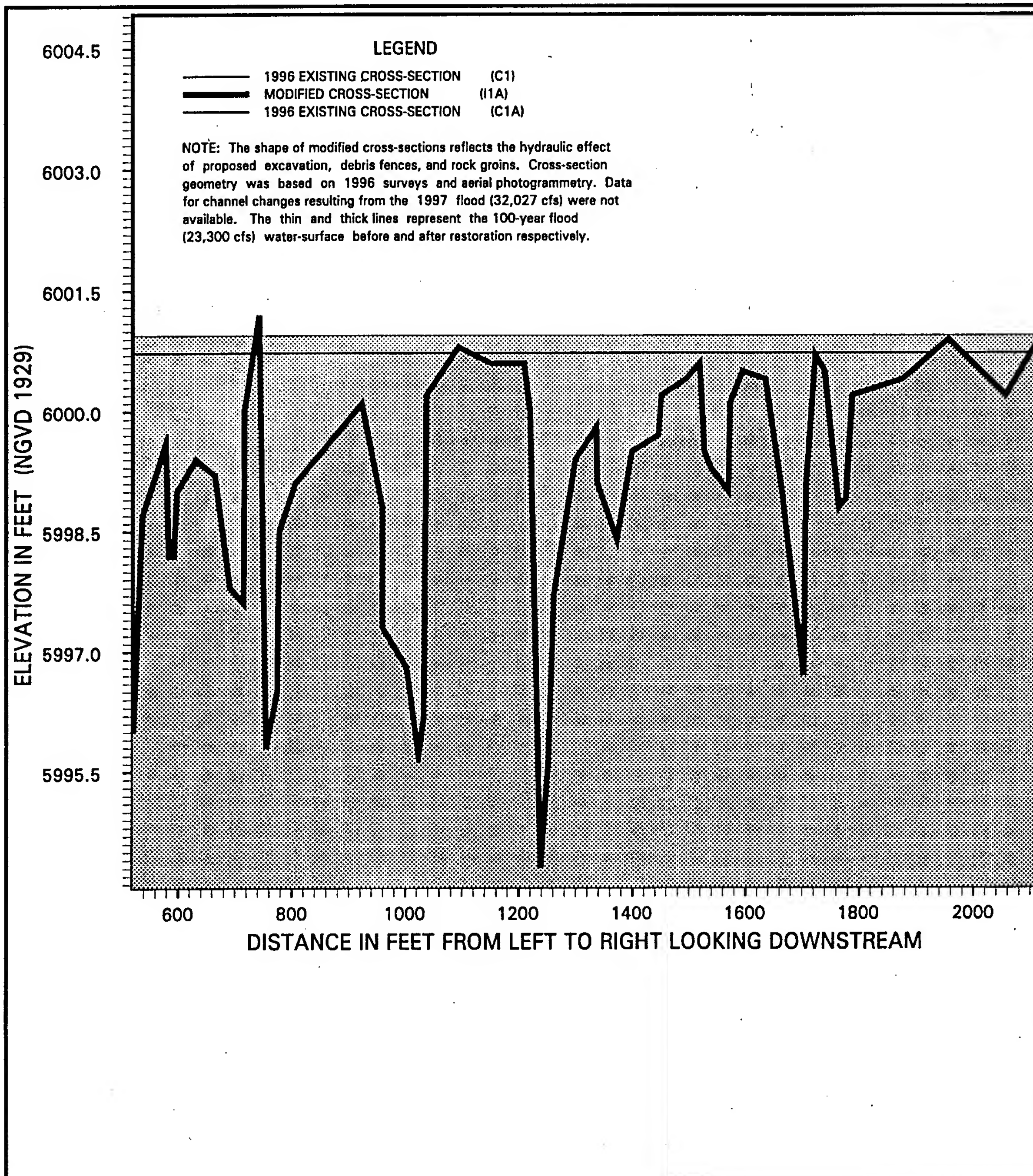
SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 201.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998

PLATE A1-7

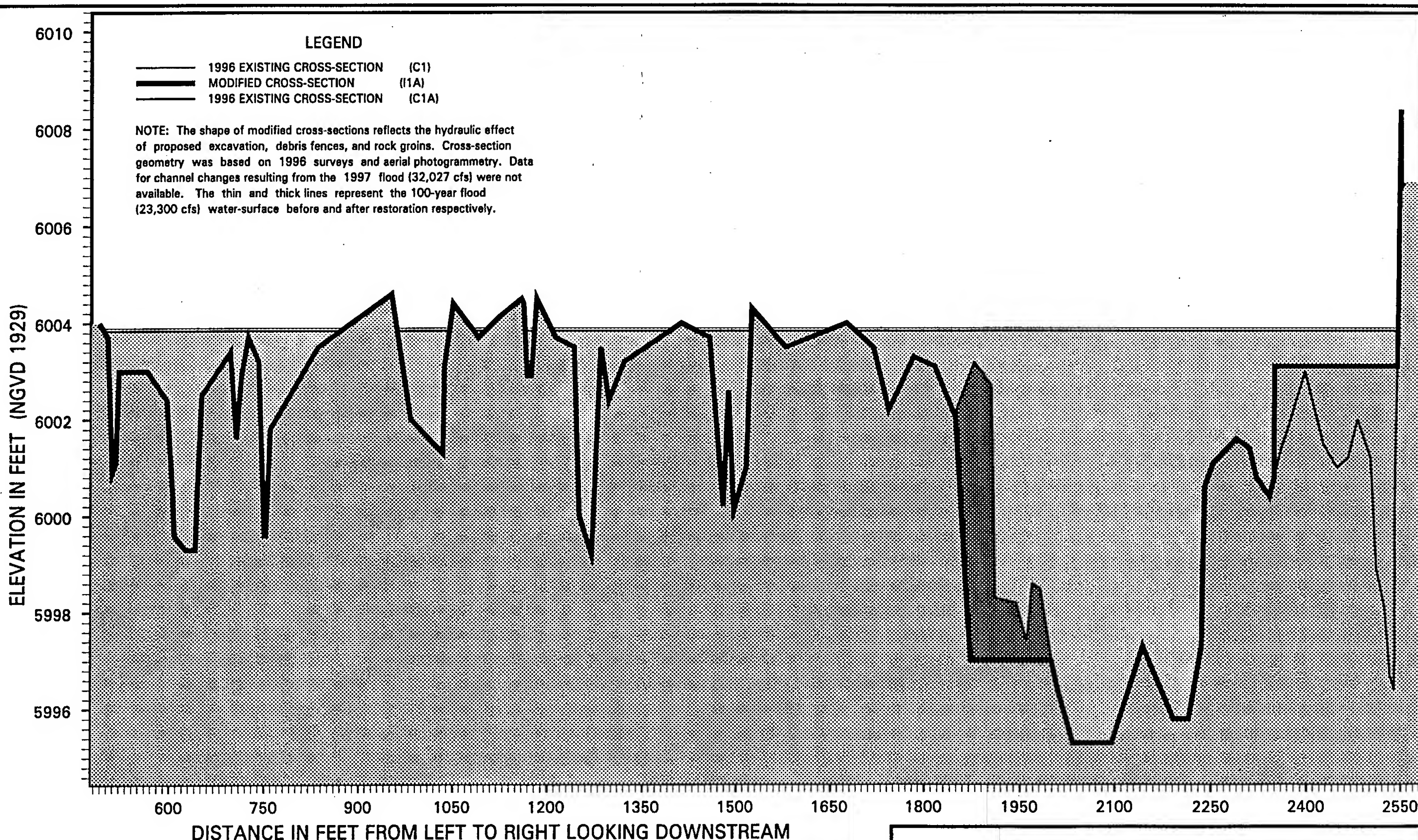


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 202.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998

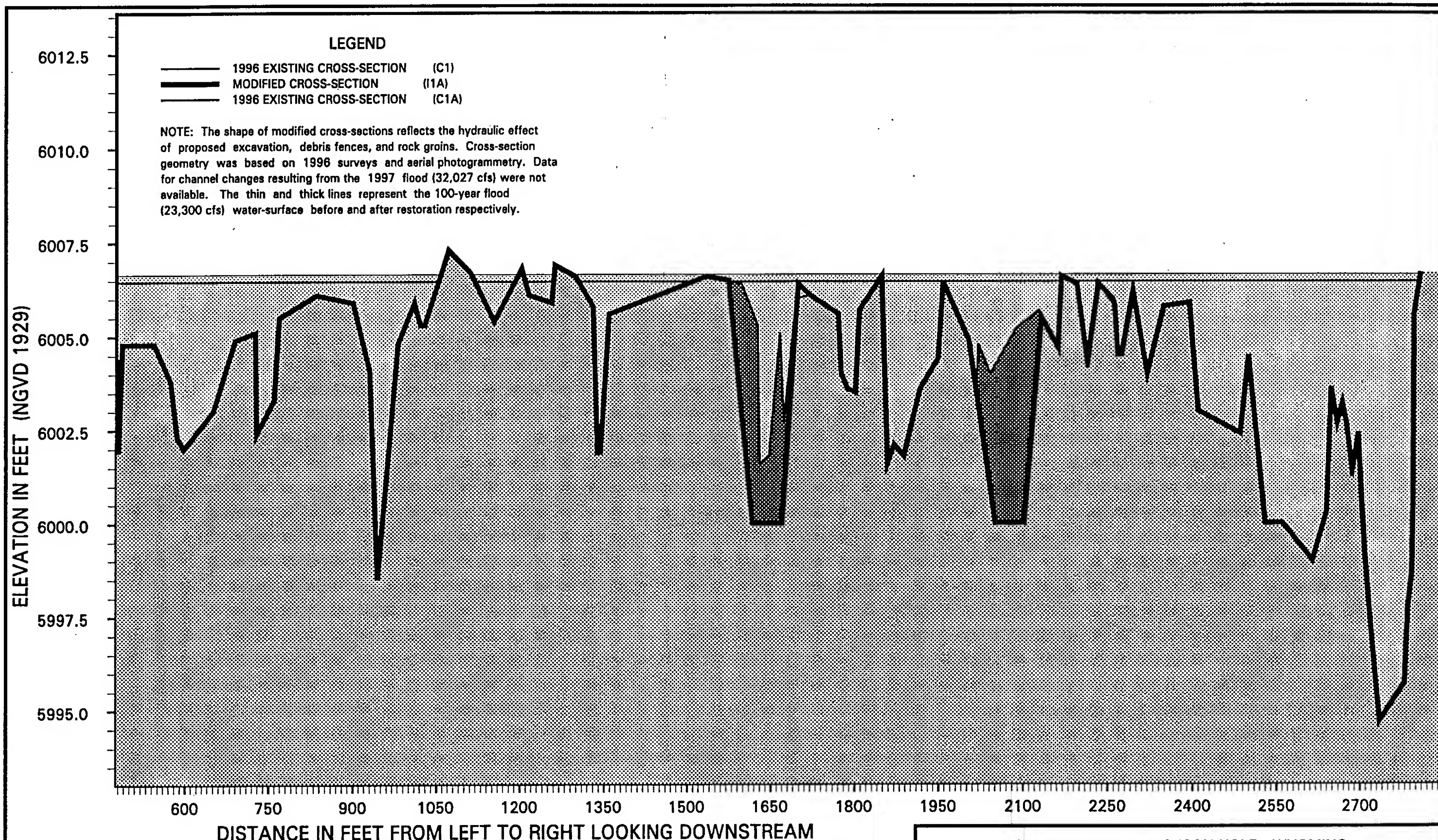


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 203.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998



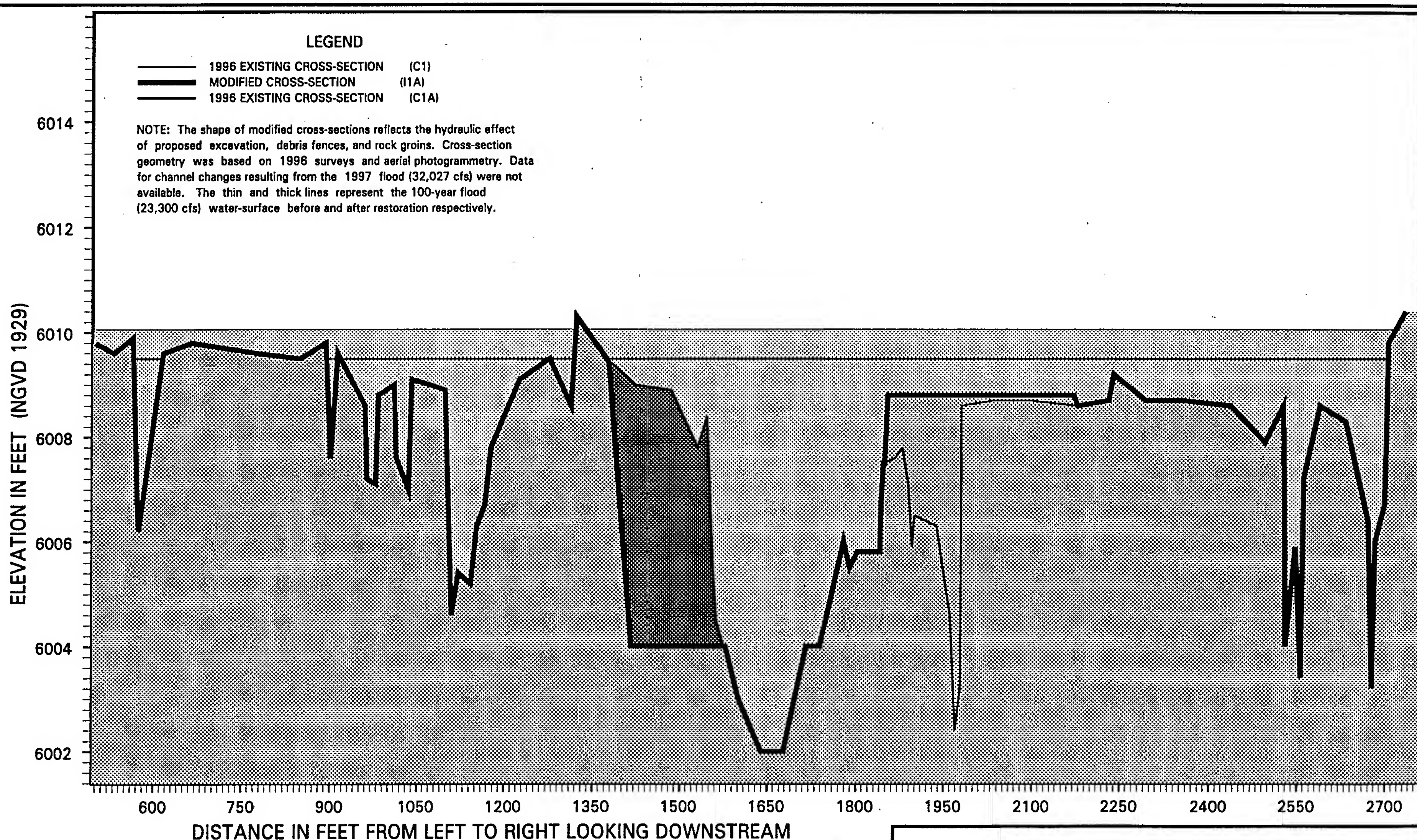
SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 204.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998

PLATE A1-10



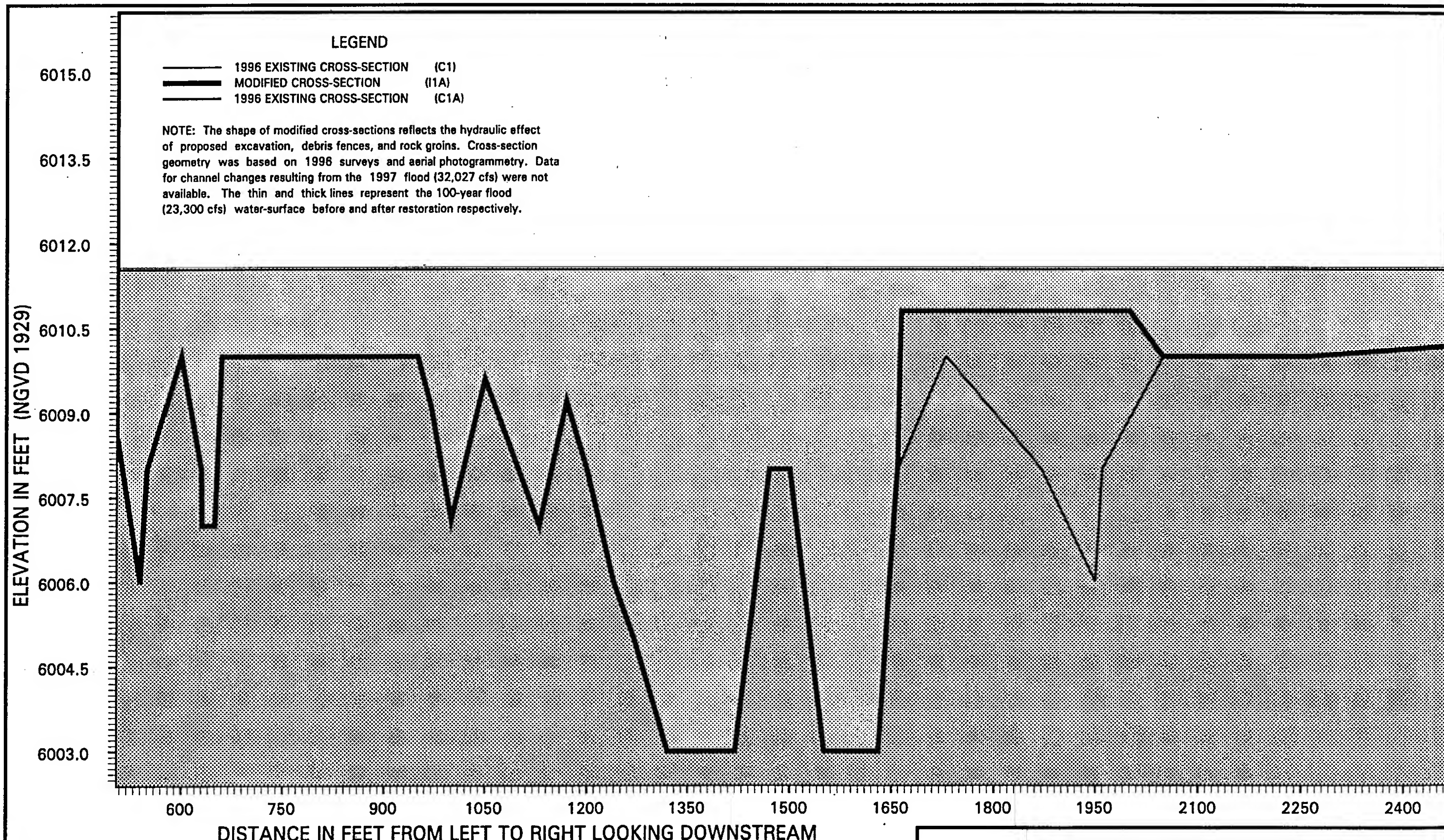
SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 205.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998

PLATE A1-11



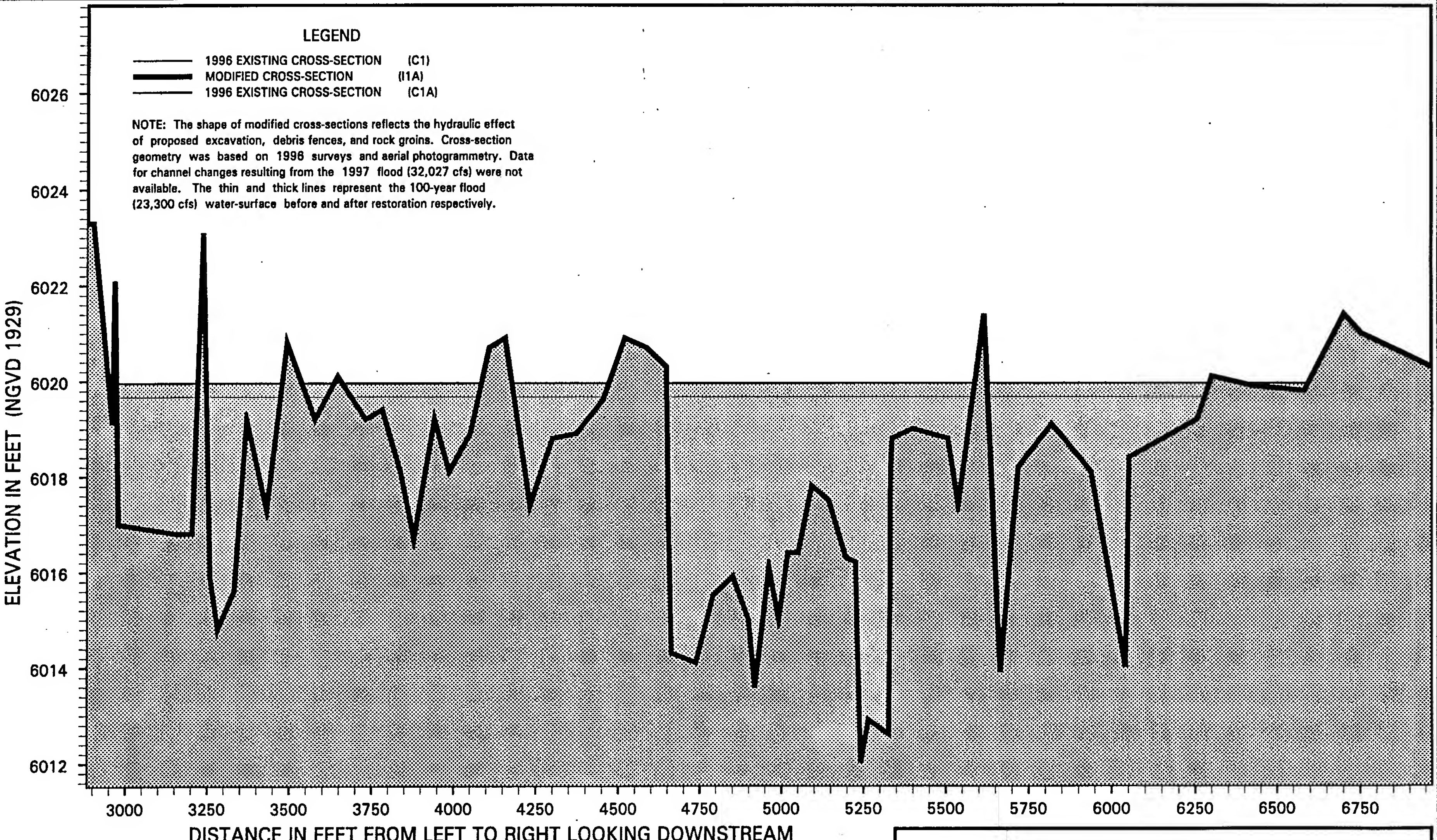
SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 205.10

WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998

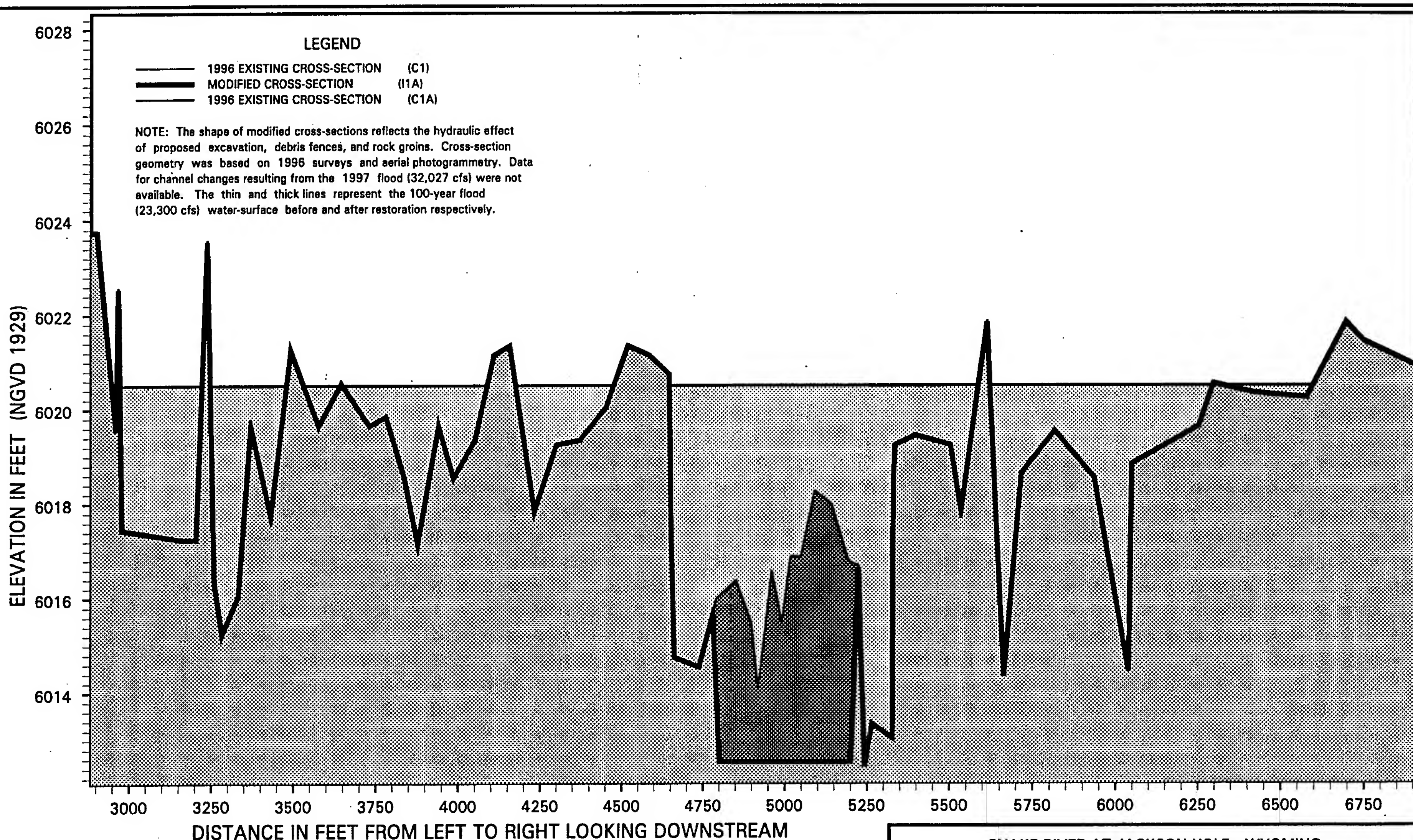


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 107.80
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998

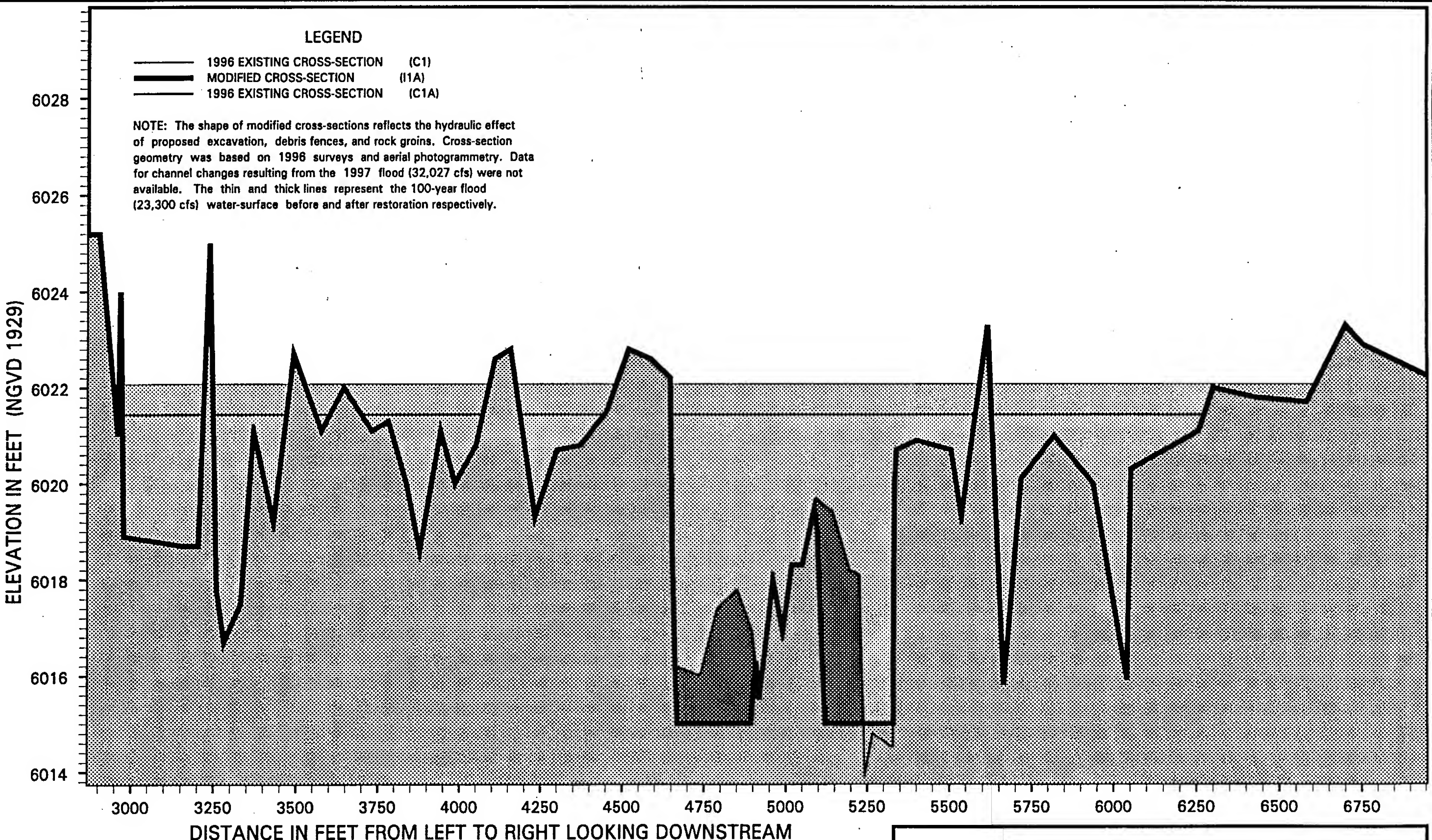


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 107.90
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998

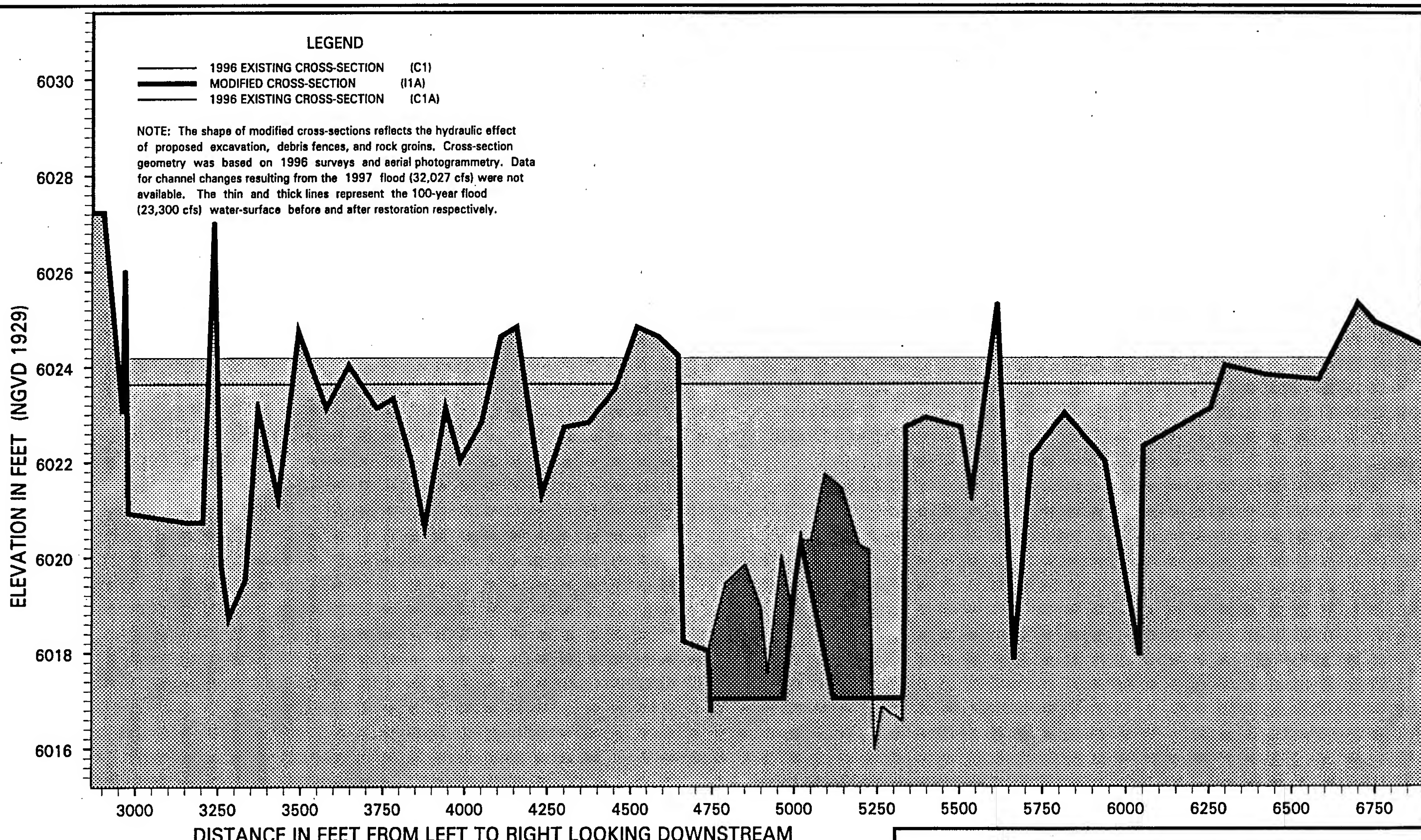


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 108.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998

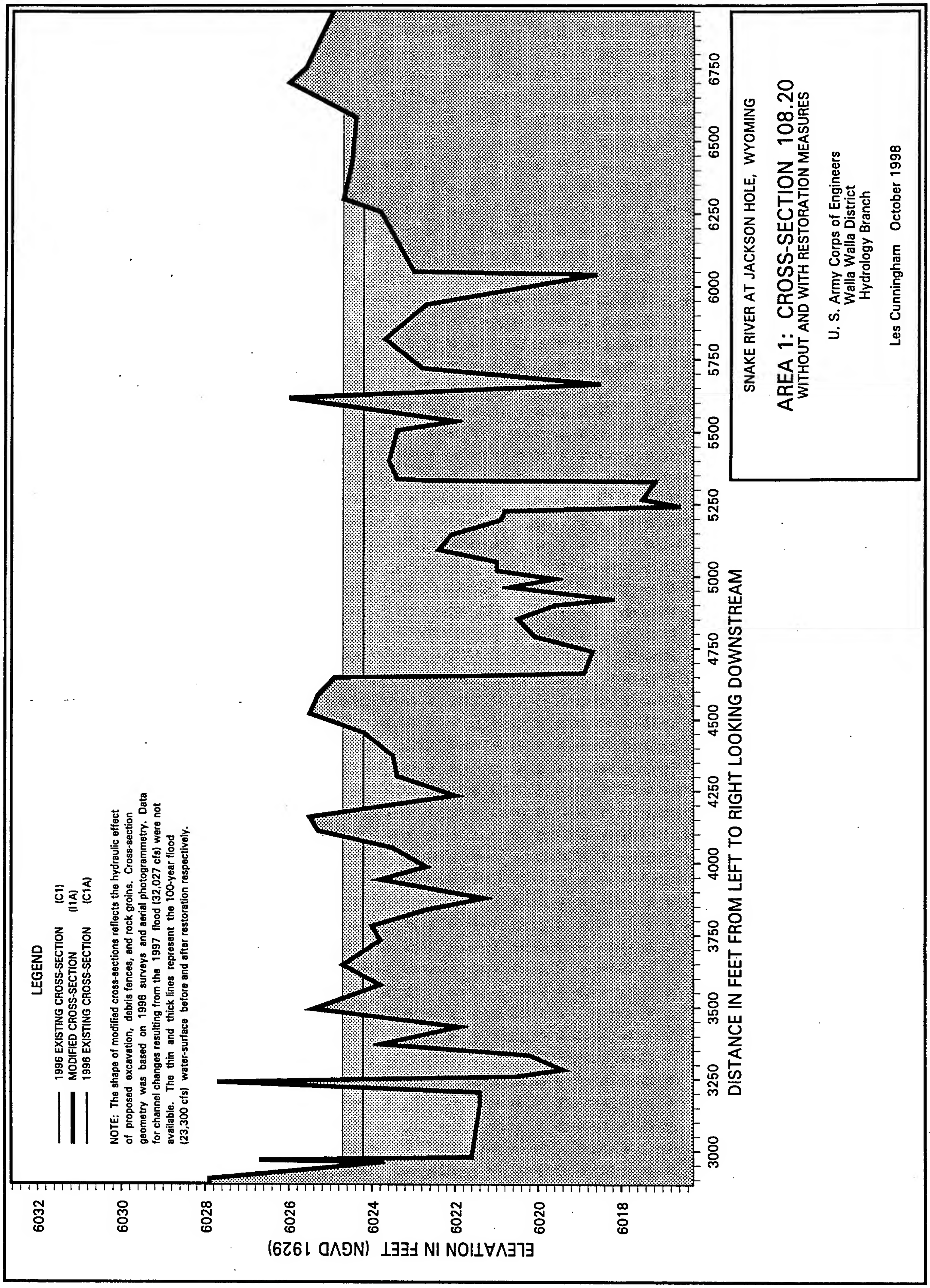


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 108.10
WITHOUT AND WITH RESTORATION MEASURES

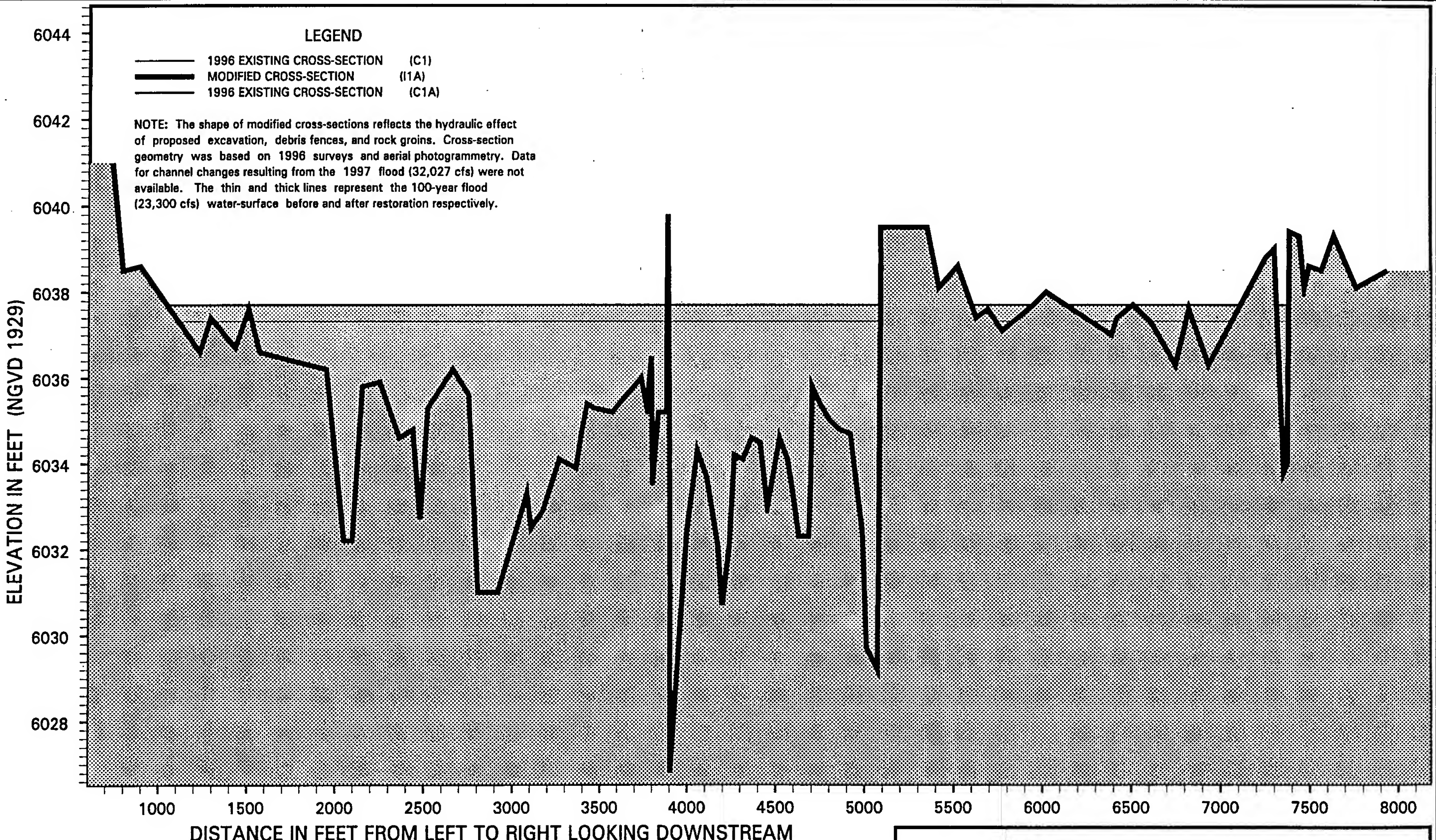
U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998



LEGEND
1996 EXISTING CROSS-SECTION (C1)
MODIFIED CROSS-SECTION (I1A)
1996 EXISTING CROSS-SECTION (C1A)
NOTE: The shape of modified cross-sections reflects the hydraulic effect of proposed excavation, debris fences, and rock groins. Cross-section geometry was based on 1996 surveys and aerial photogrammetry. Data for channel changes resulting from the 1997 flood (32,027 cfs) were not available. The thin and thick lines represent the 100-year flood (23,300 cfs) water-surface before and after restoration respectively.
ELEVATION IN FEET (NGVD 1929)
6018
6020
6022
6024
6026
6028
6030
6032
DISTANCE IN FEET FROM LEFT TO RIGHT LOOKING DOWNSTREAM
3000
3250
3500
3750
4000
4250
4500
4750
5000
5250
5500
5750
6000
6250
6500
6750
SNAKE RIVER AT JACKSON HOLE, WYOMING
AREA 1: CROSS-SECTION 108.20
WITHOUT AND WITH RESTORATION MEASURES
U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch
Les Cunningham October 1998

PLATE A1-17



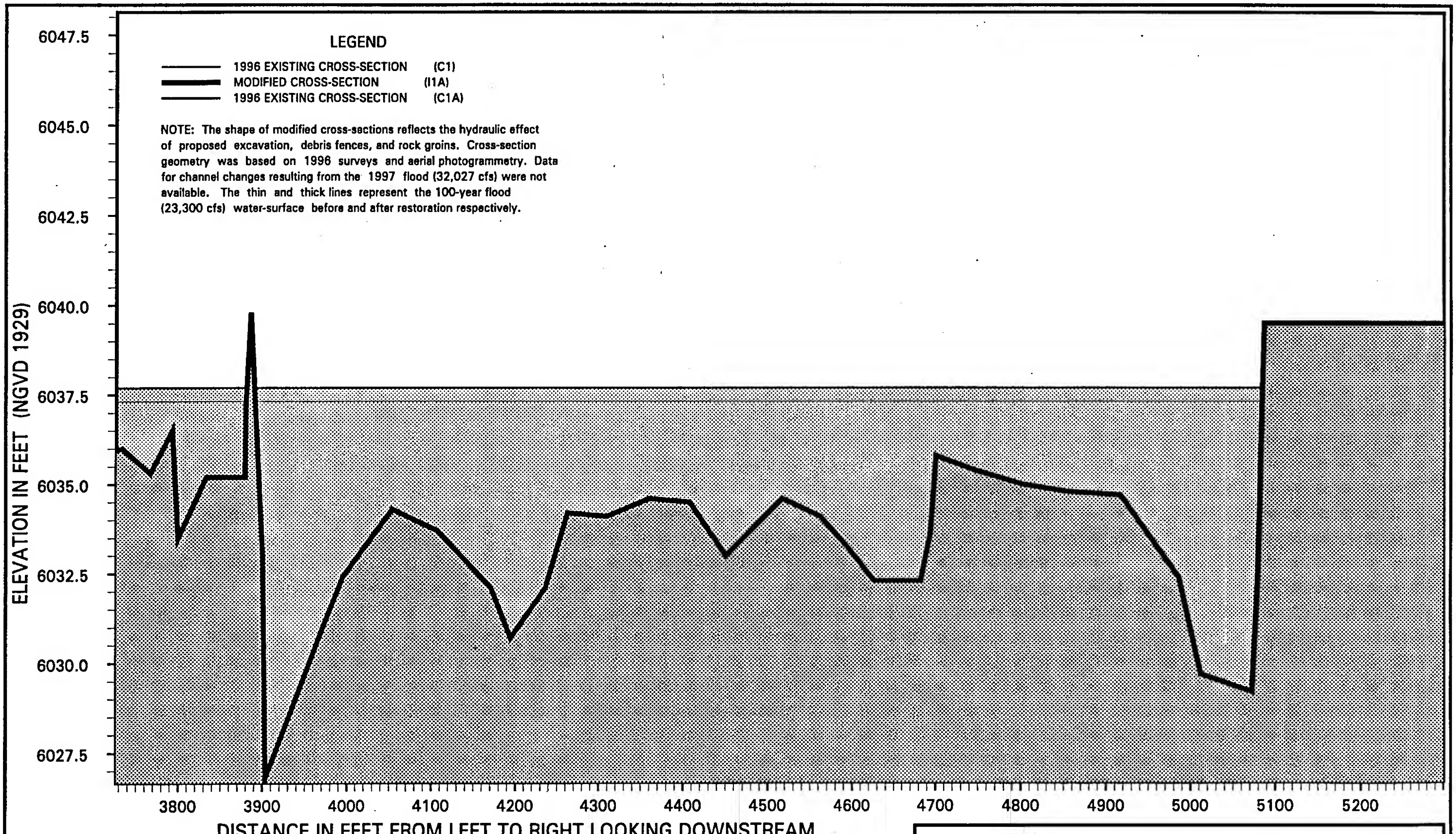
SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 109.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998

PLATE A1-18



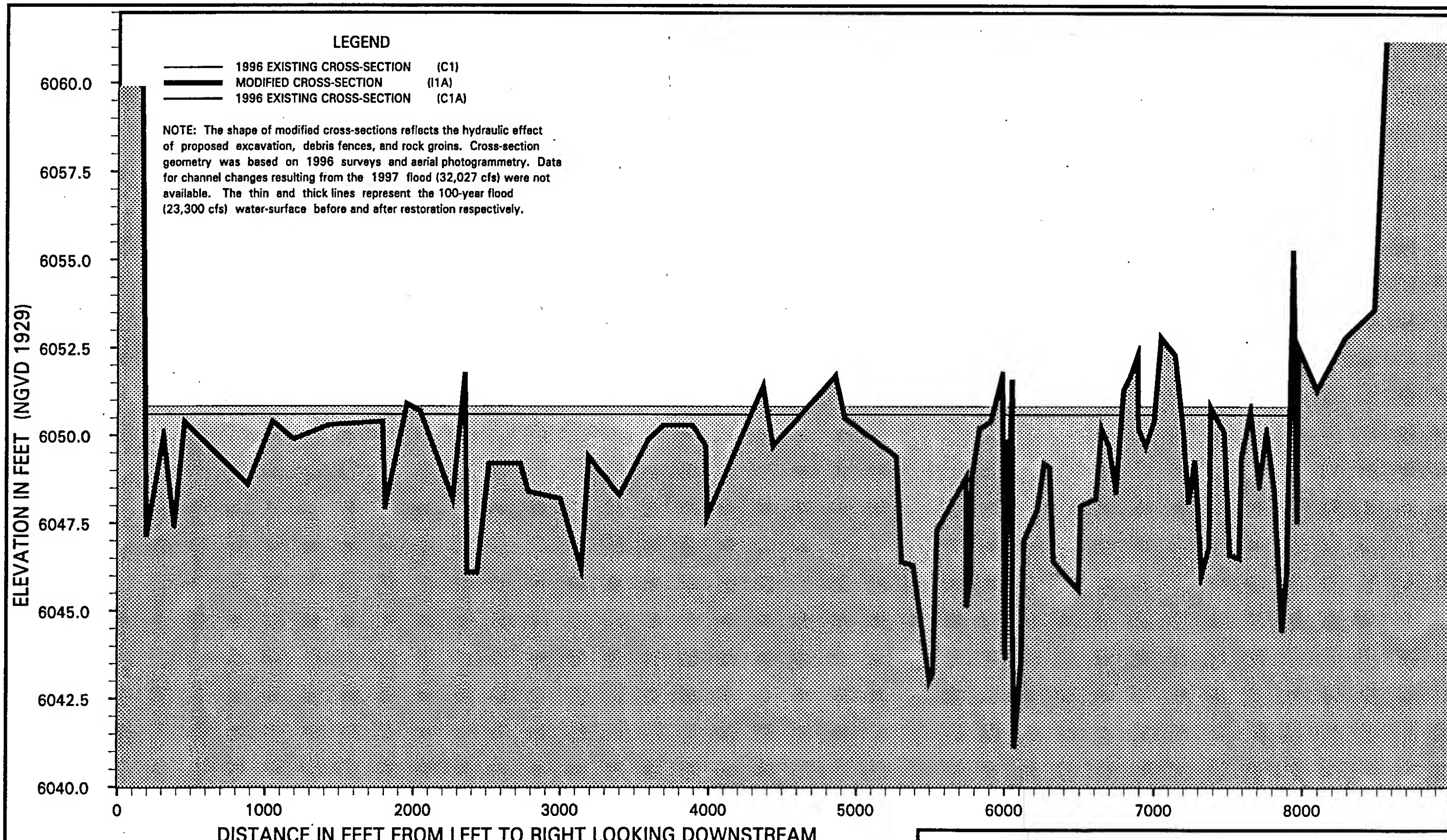
SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 109.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998

PLATE A1-19

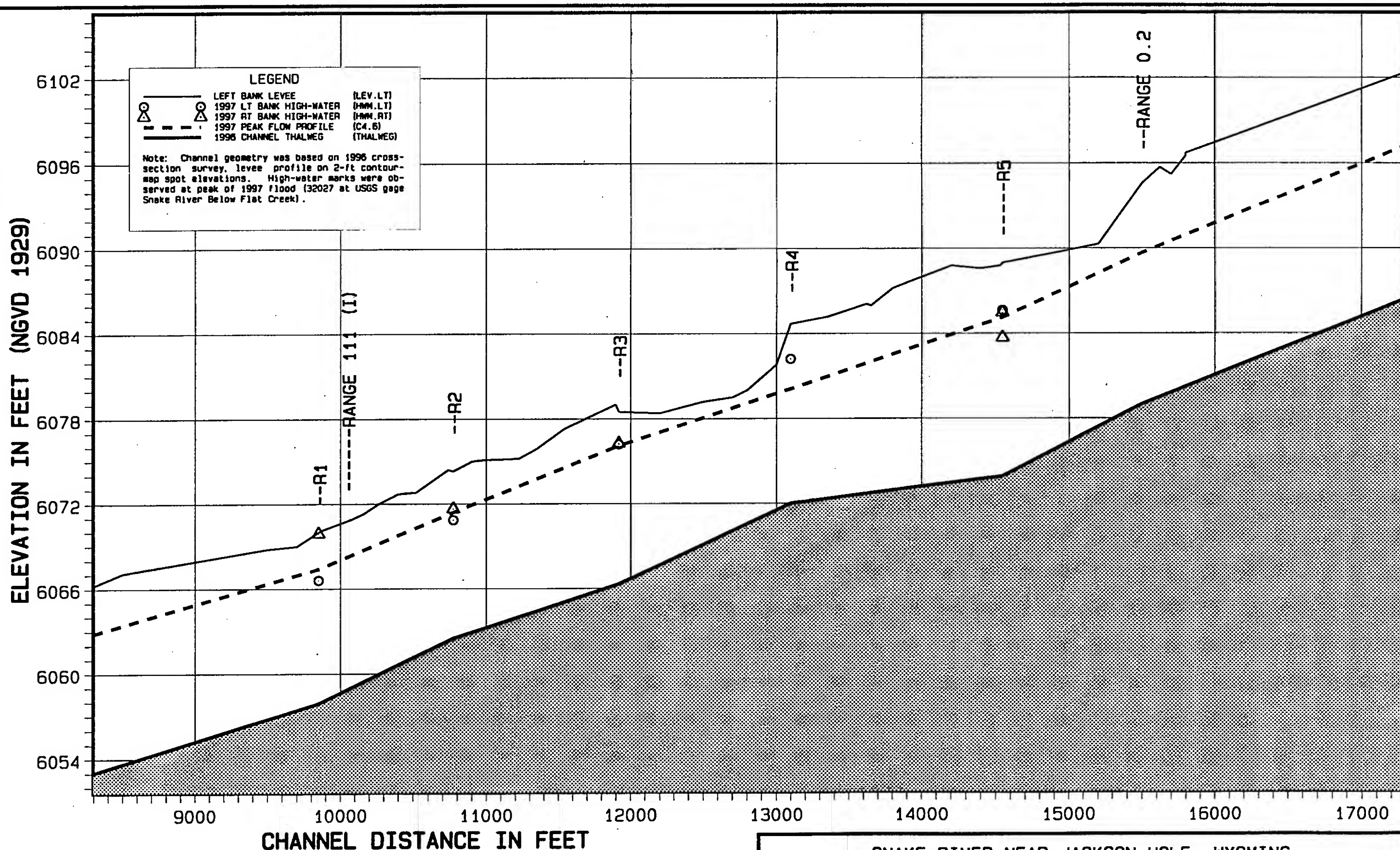


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 1: CROSS-SECTION 110.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham October 1998

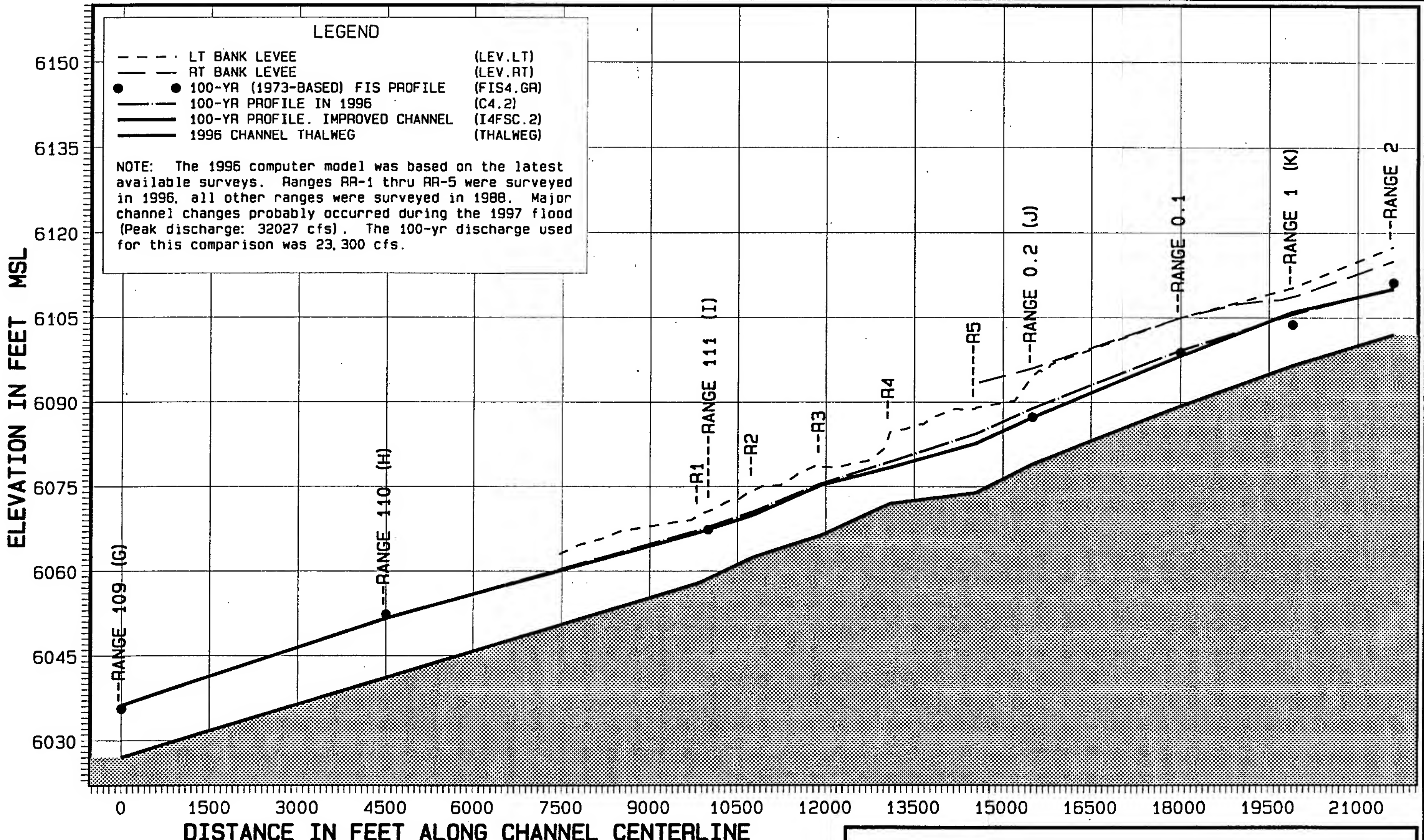


SNAKE RIVER NEAR JACKSON HOLE, WYOMING
JACKSON HOLE ENVIRONMENTAL RESTORATION STUDY

OBSERVED VS CALCULATED WATER-SURFACE PROFILES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

22 JUL 1998

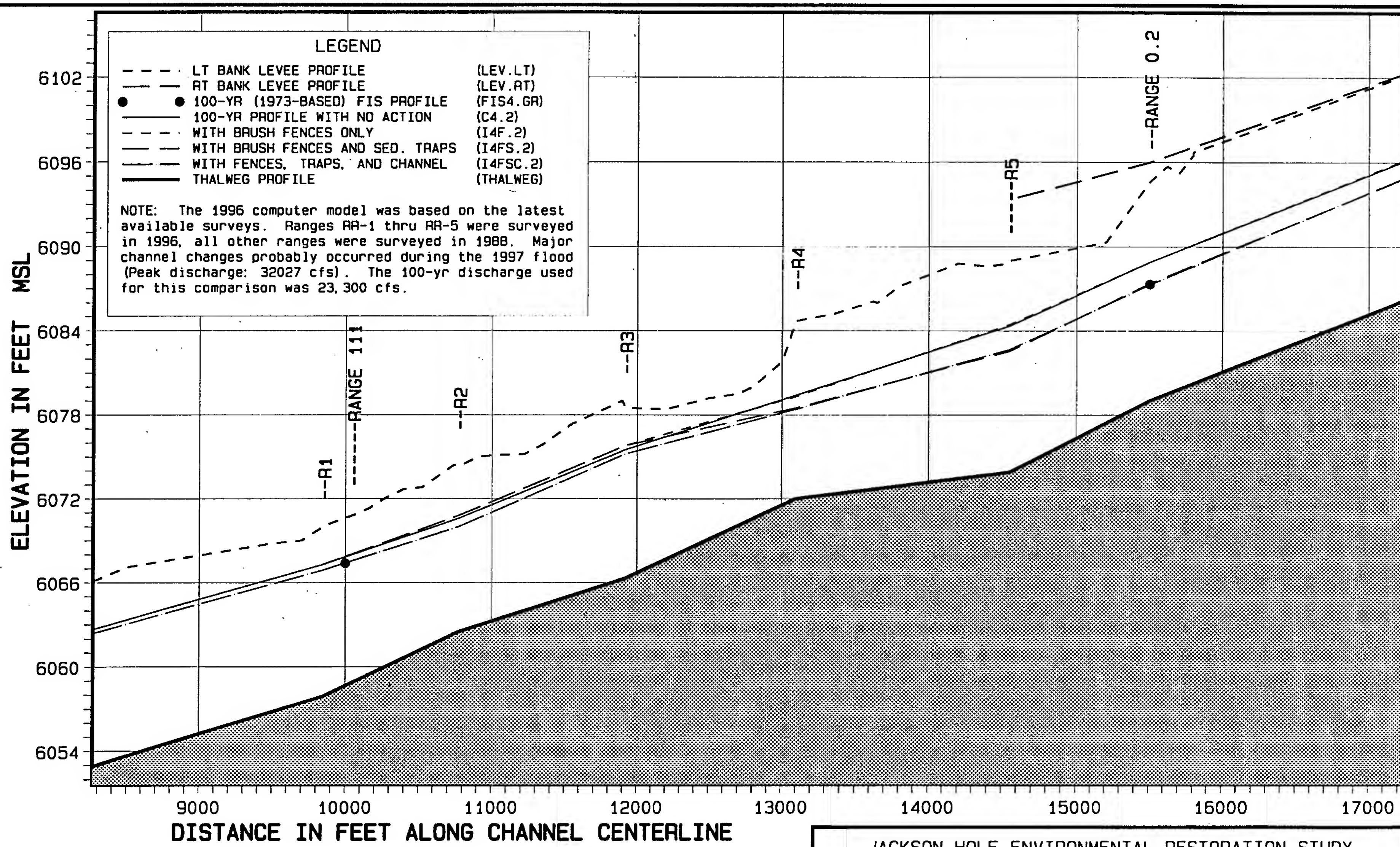


JACKSON HOLE ENVIRONMENTAL RESTORATION STUDY

AREA 4: 100-YEAR FLOOD PROFILES
EXISTING COMPARED WITH IMPROVED CHANNEL

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

29 JUL 1998



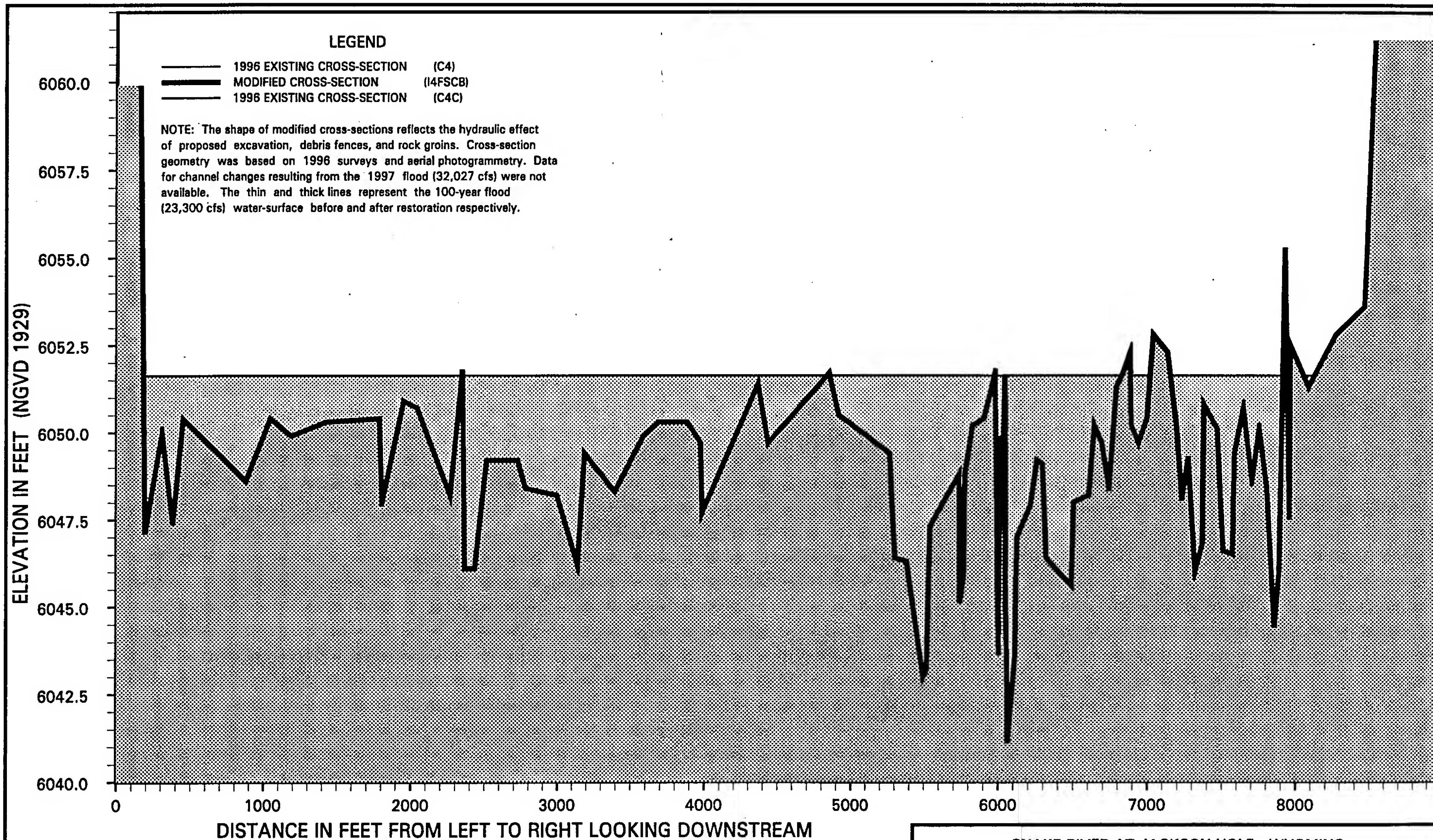
JACKSON HOLE ENVIRONMENTAL RESTORATION STUDY

AREA 4: 100-YEAR FLOOD PROFILES
EFFECTS OF DIFFERENT RESTORATION ELEMENTS

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

29 JUL 1998

PLATE A4-3

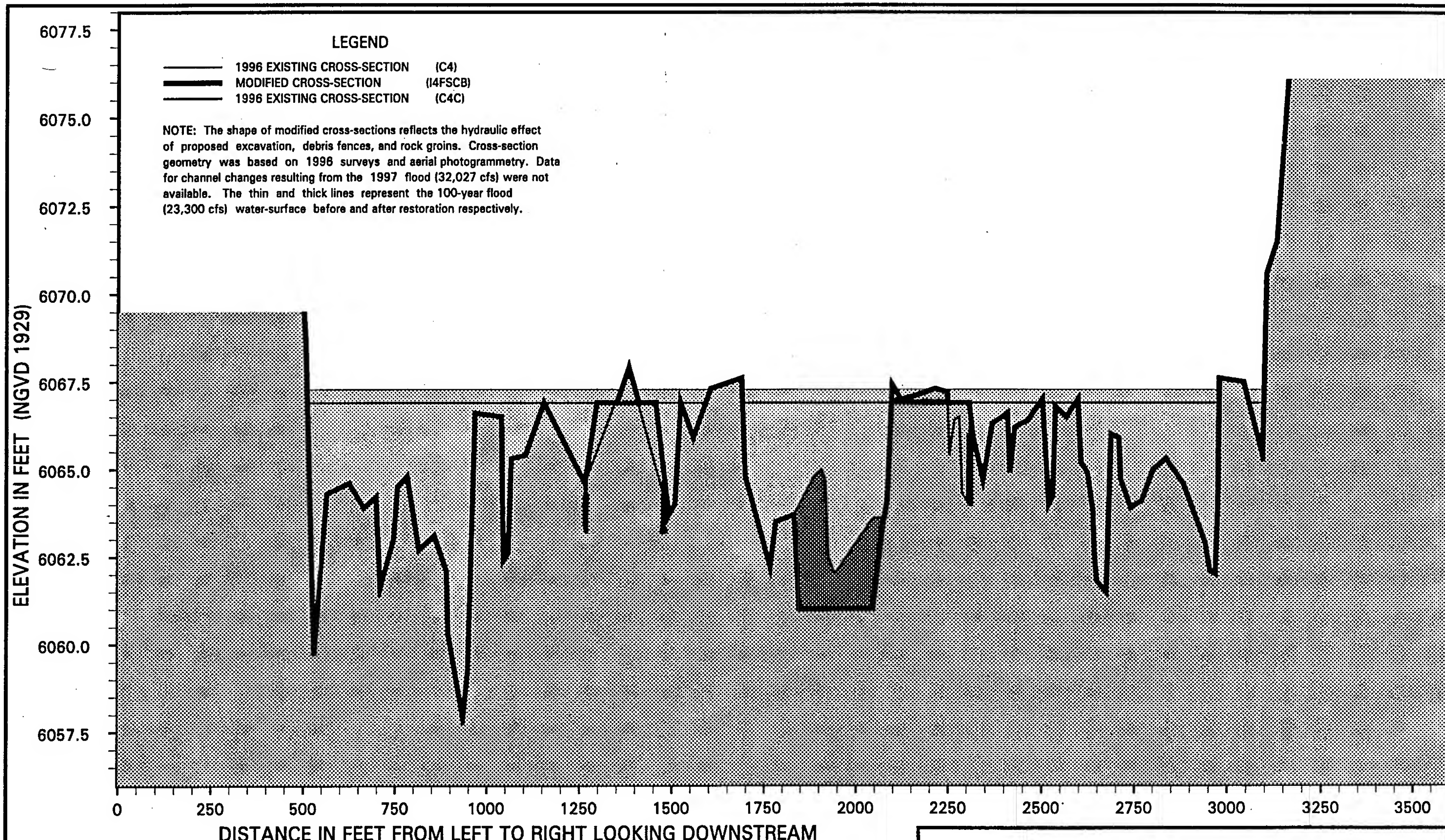


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 4: CROSS-SECTION 110.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham August 1998

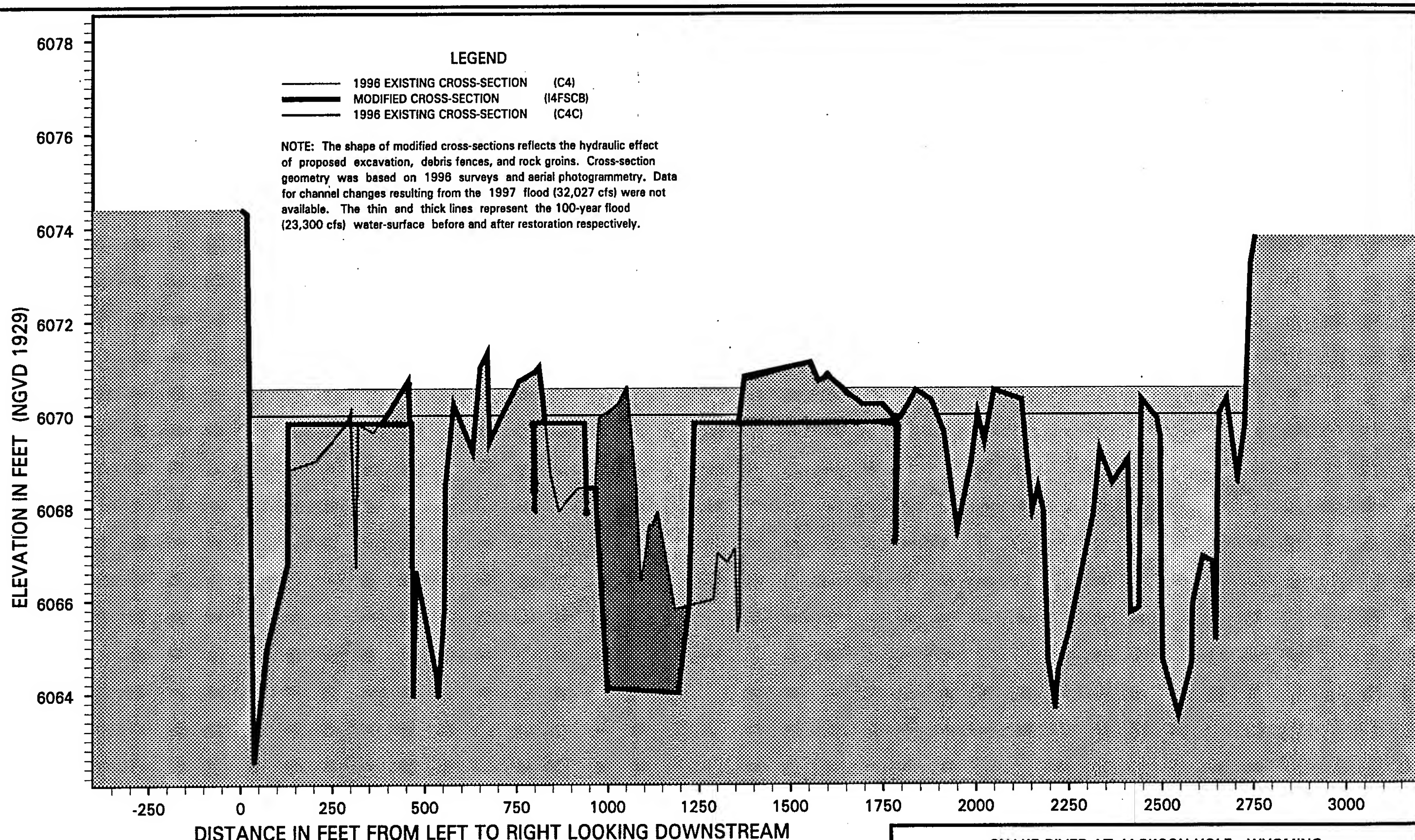


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 4: CROSS-SECTION R1
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham August 1998

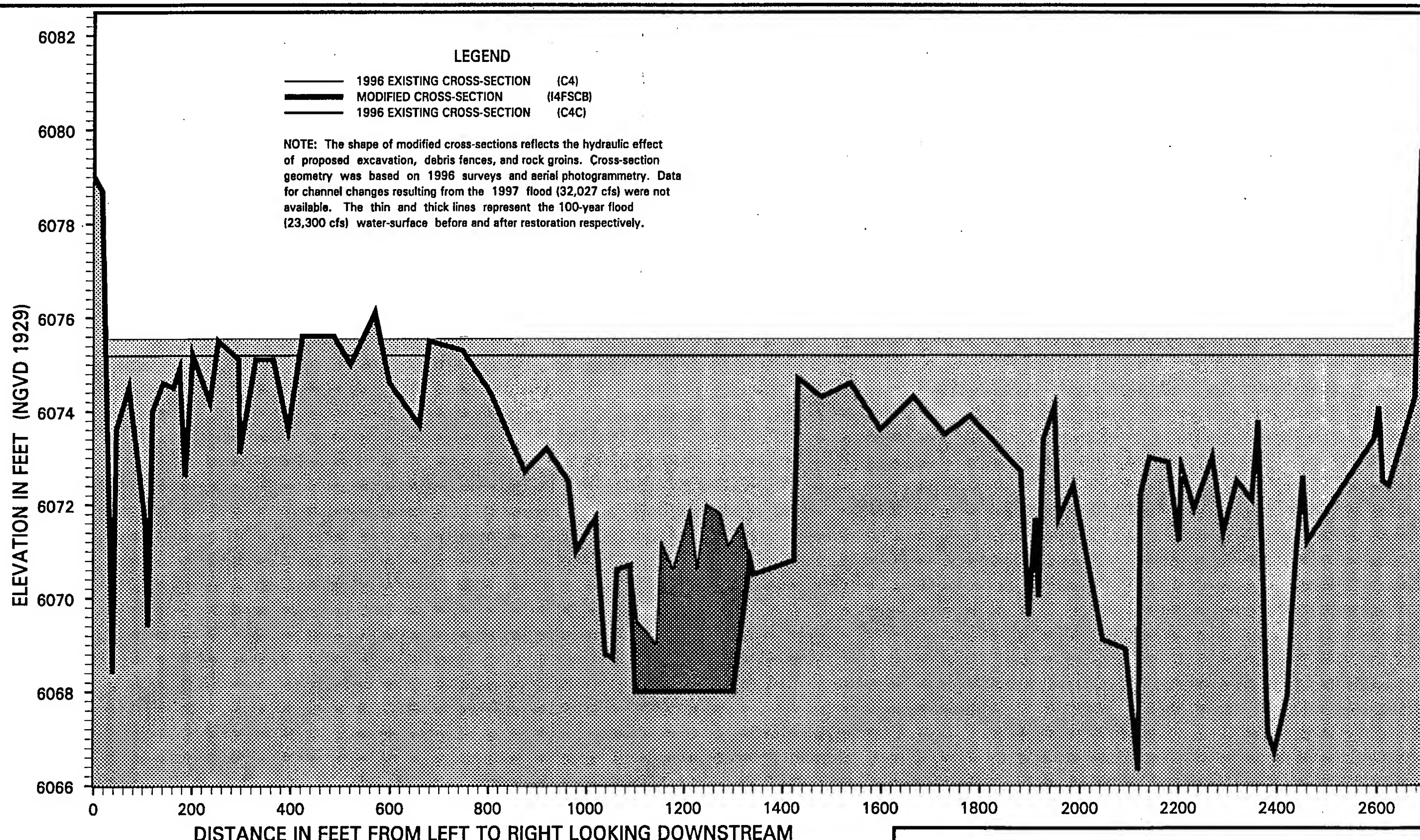


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 4: CROSS-SECTION R2
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham August 1998

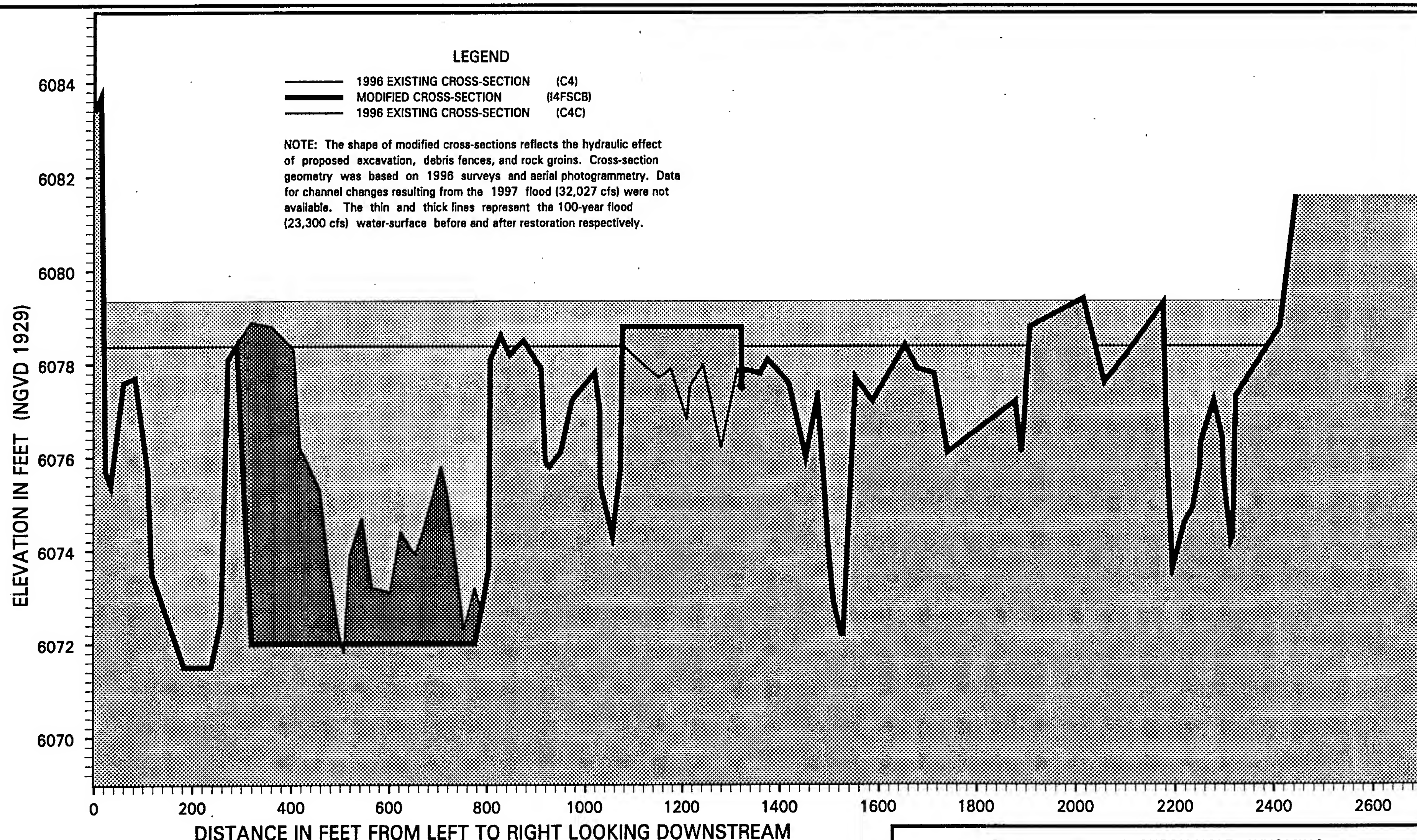


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 4: CROSS-SECTION R3
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham August 1998



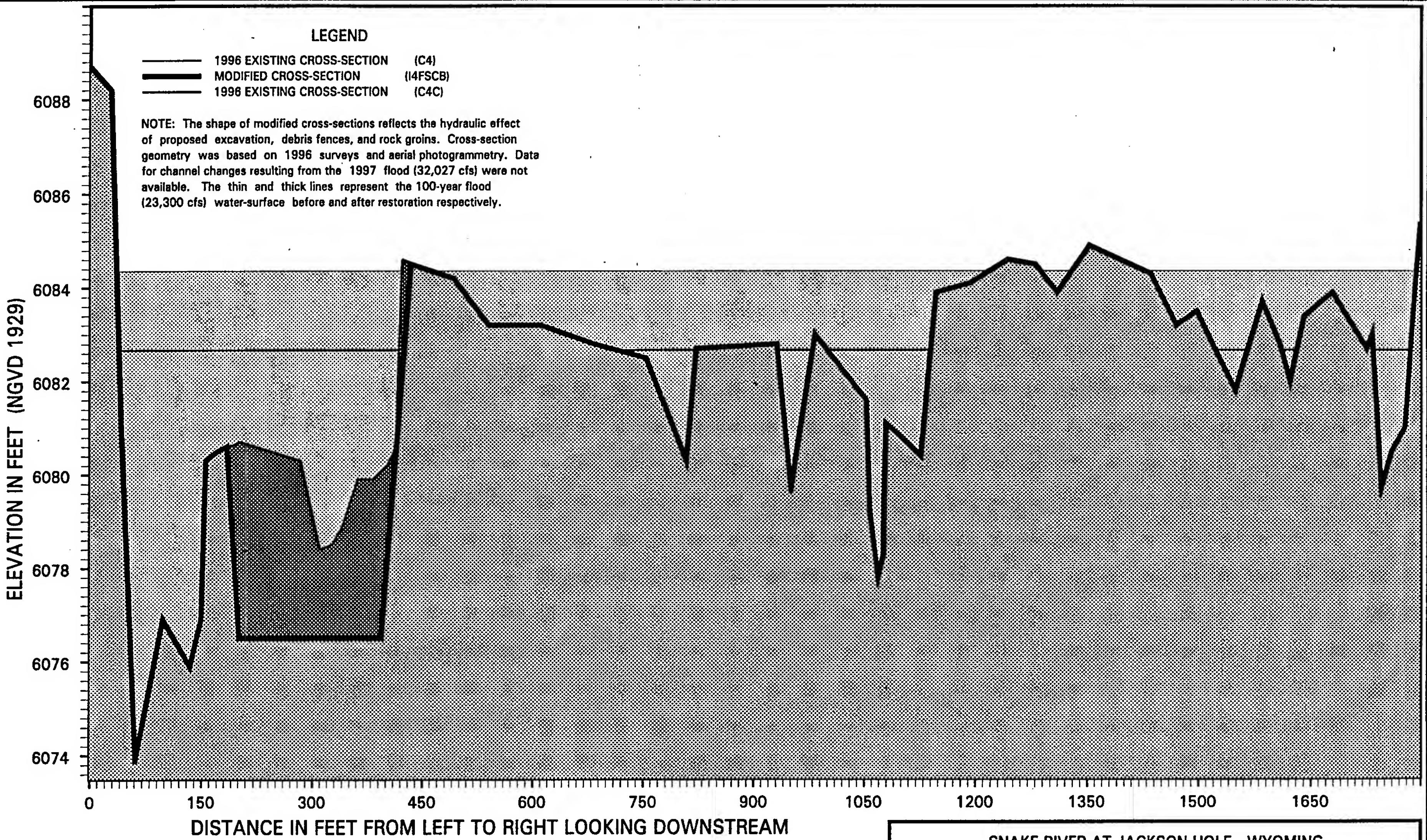
SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 4: CROSS-SECTION R4
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham August 1998

PLATE A4-8

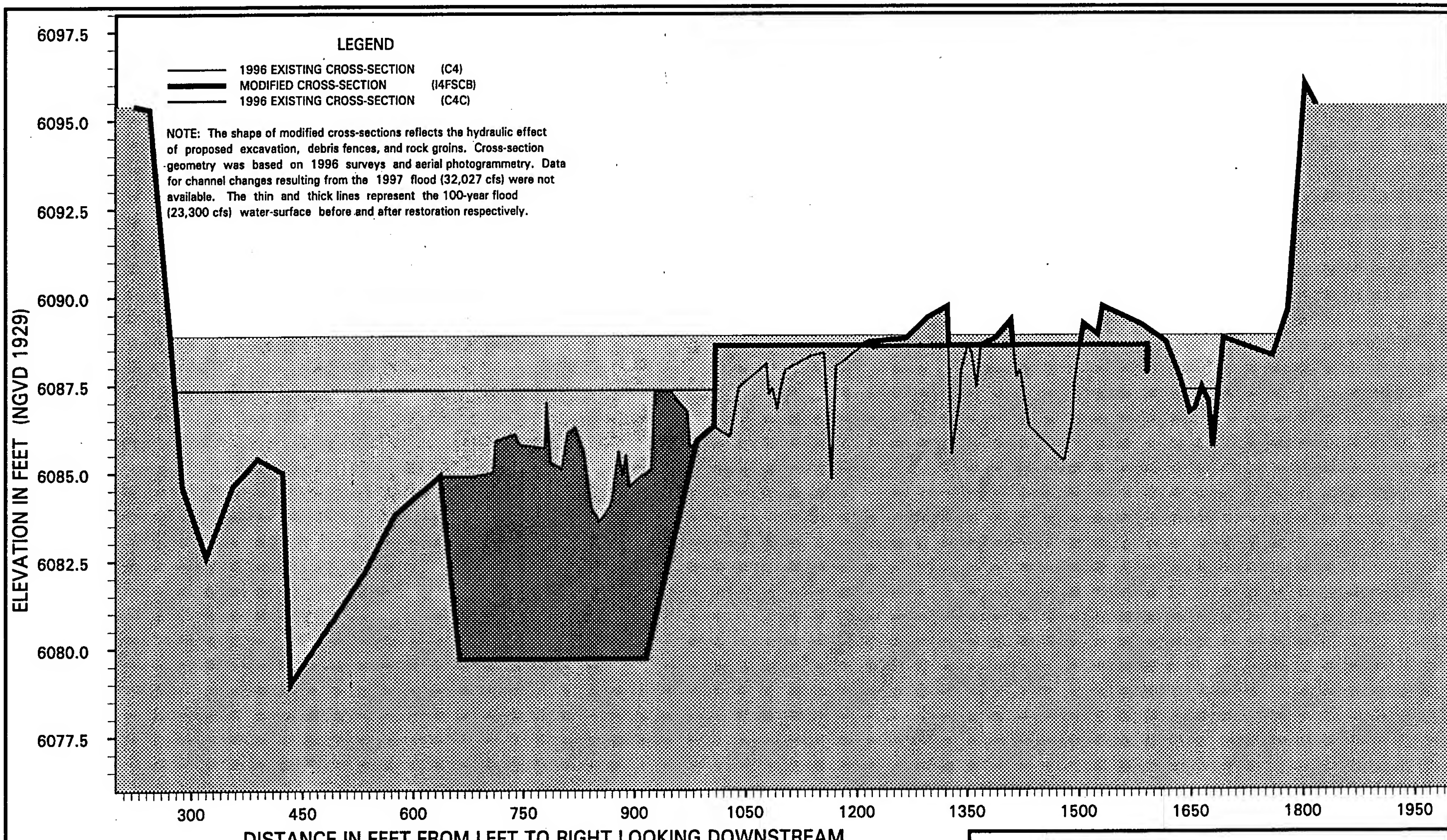


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 4: CROSS-SECTION R5
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham August 1998

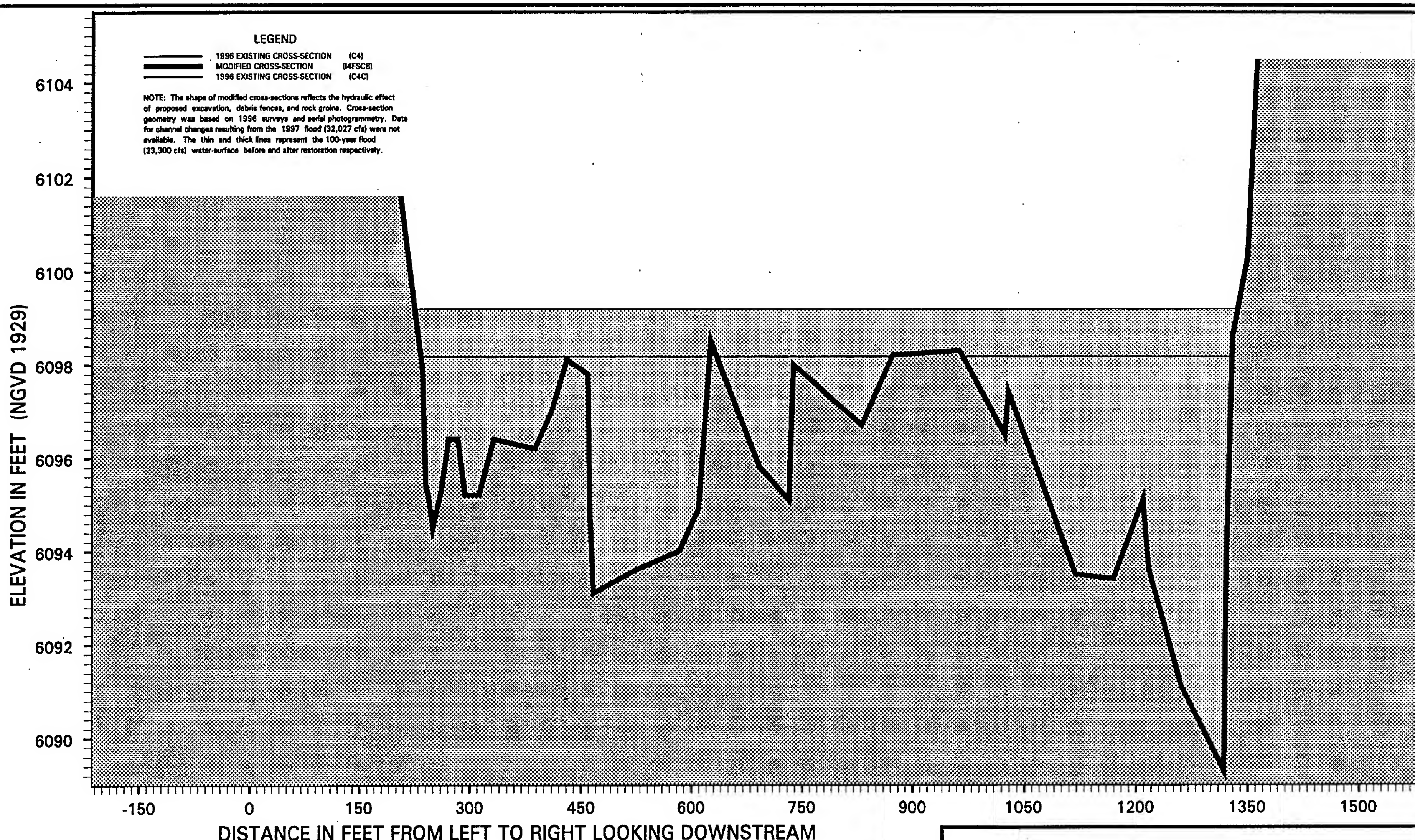


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 4: CROSS-SECTION .20
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham August 1998

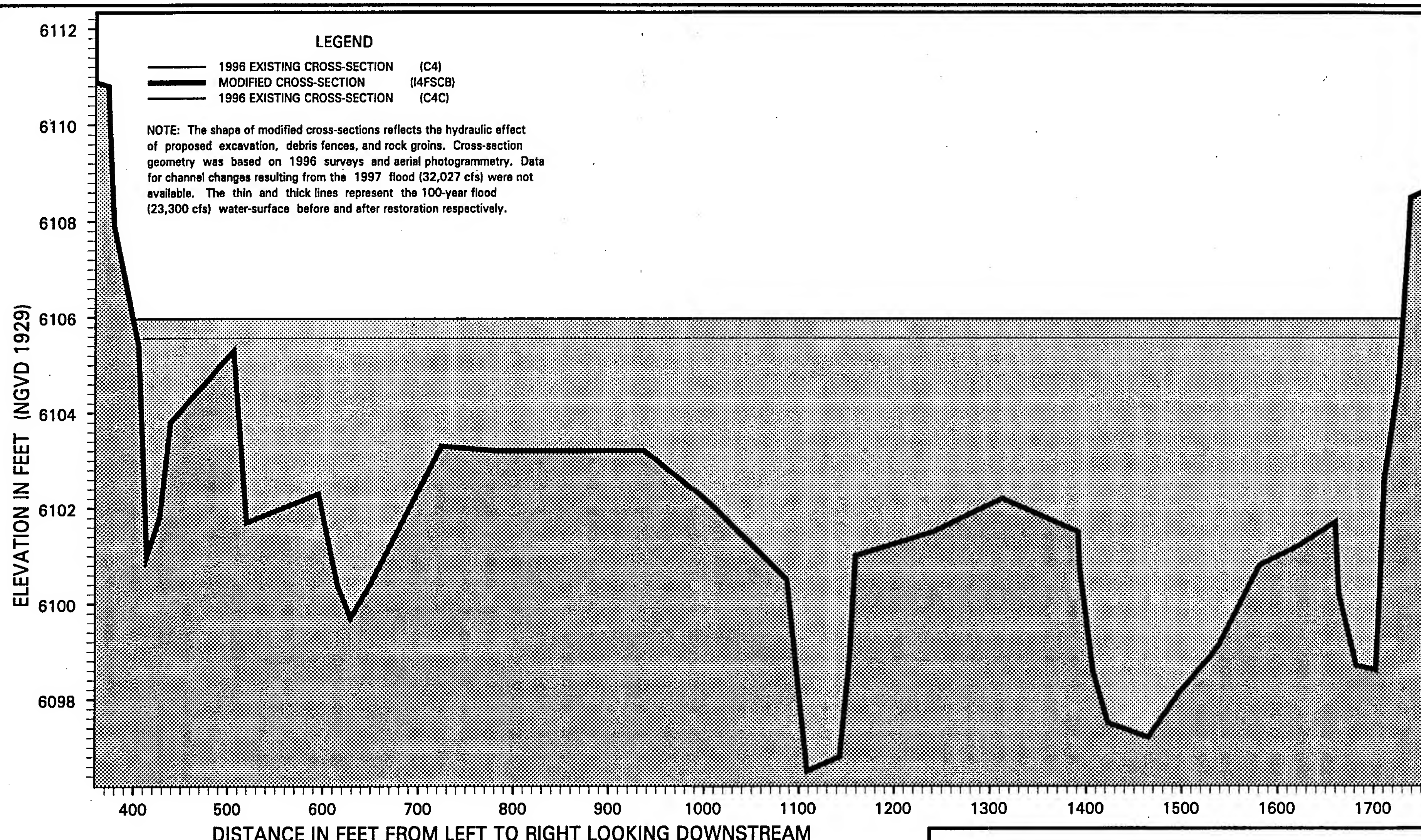


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 4: CROSS-SECTION .10
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham August 1998



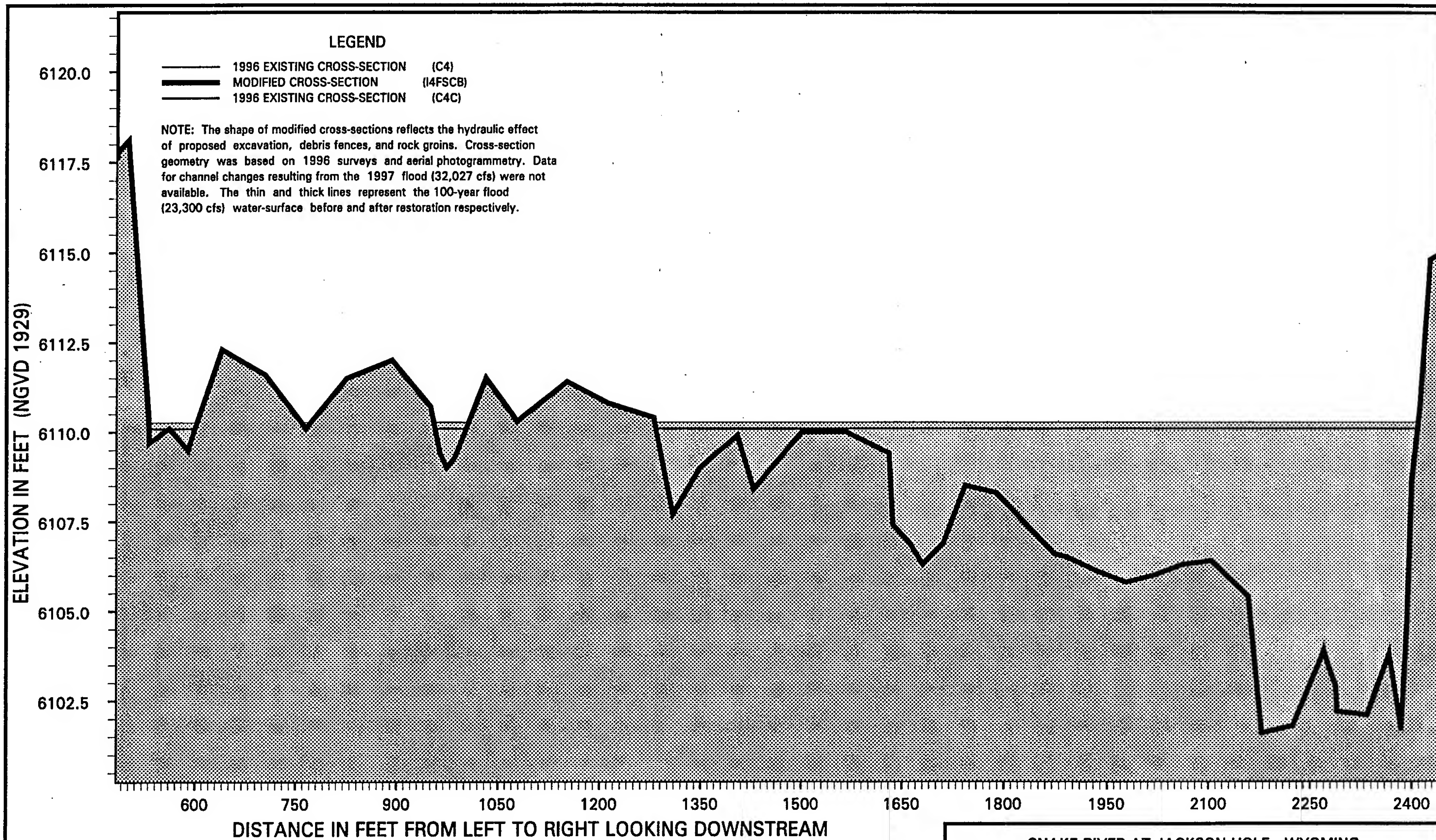
SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 4: CROSS-SECTION 1.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham August 1998

PLATE A4-12



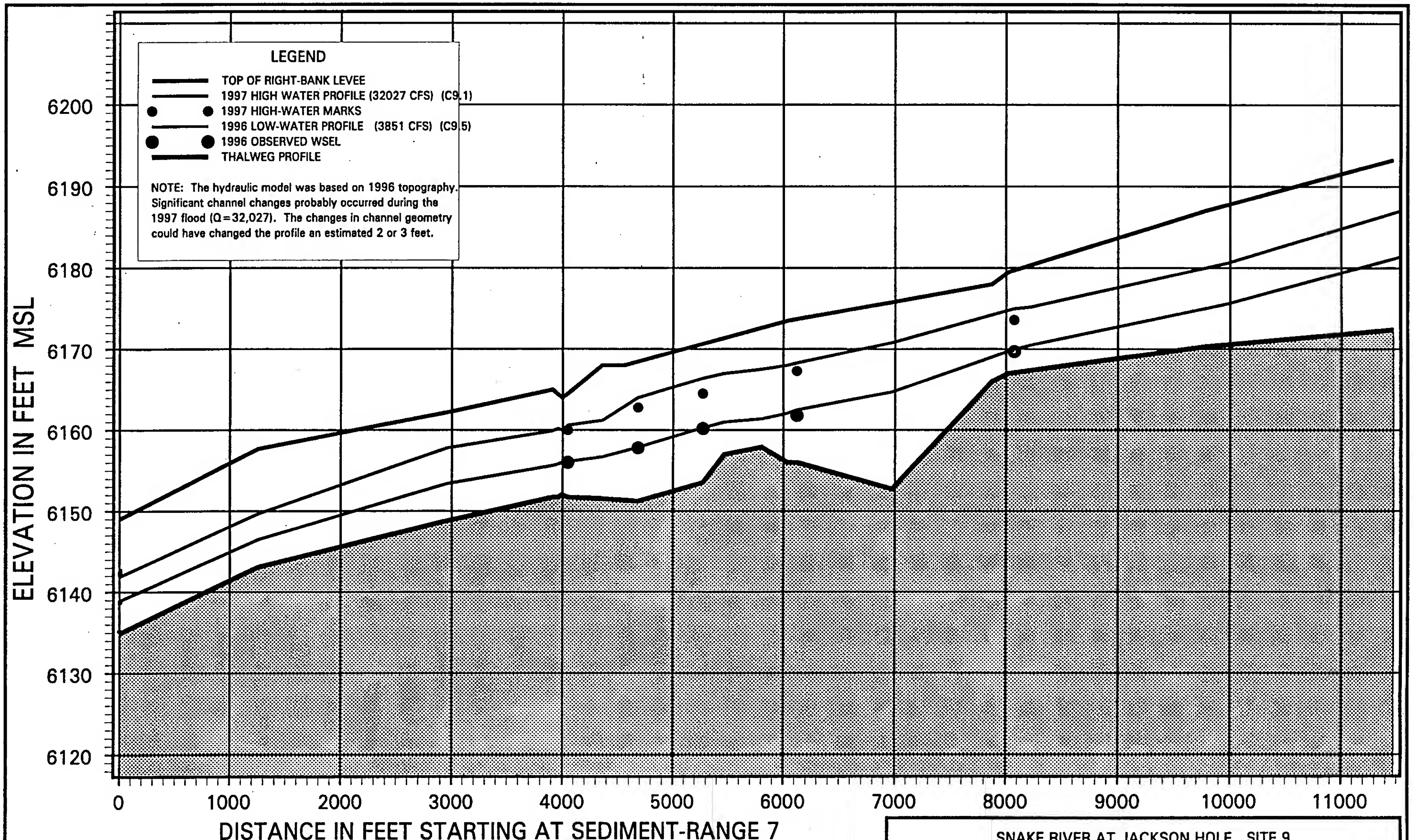
SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 4: CROSS-SECTION 2.00

WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

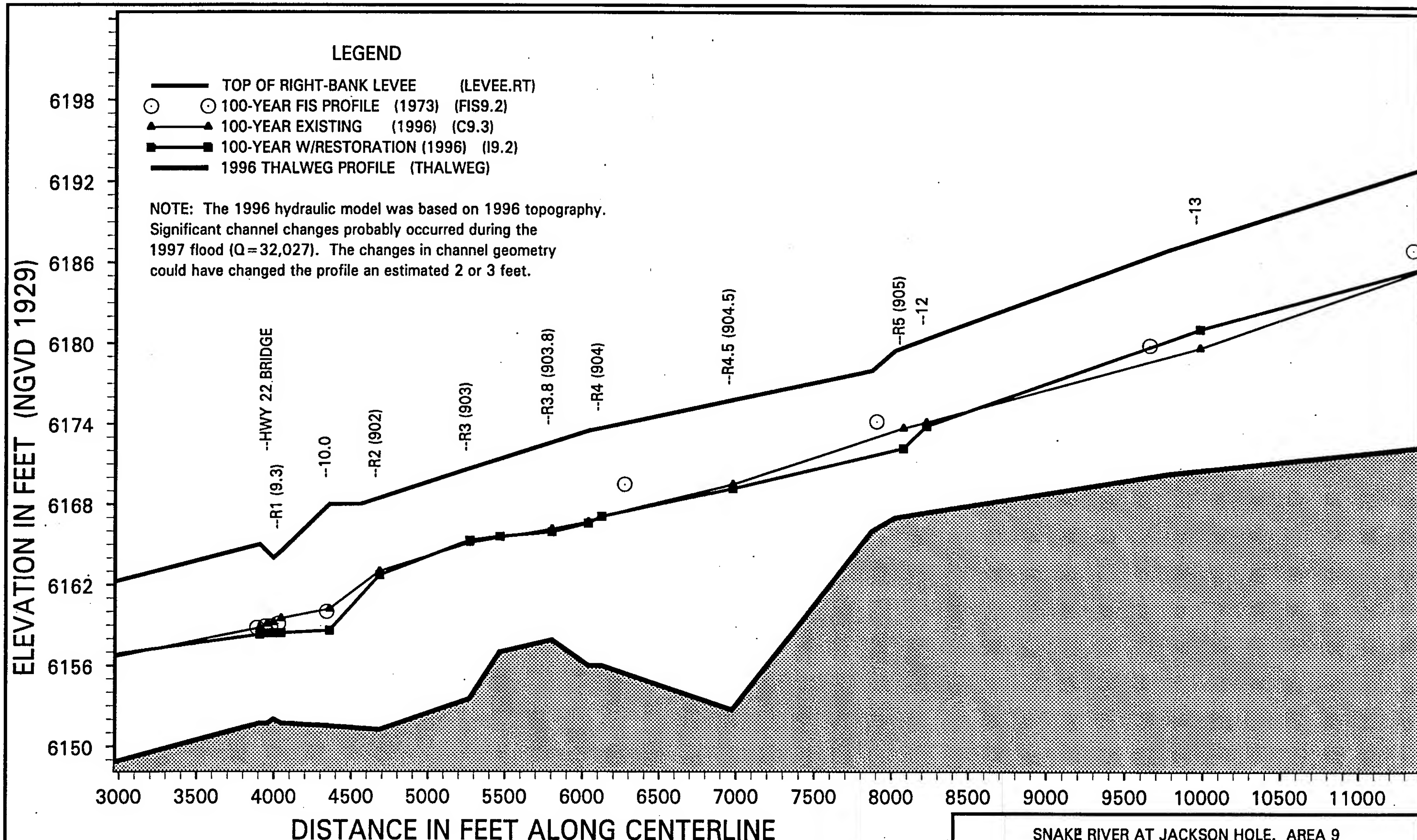
Les Cunningham August 1998



SNAKE RIVER AT JACKSON HOLE. SITE 9

1997 HIGH FLOW & 1996 LOW-FLOW
COMPARED WITH HIGH-WATER MARKS

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch



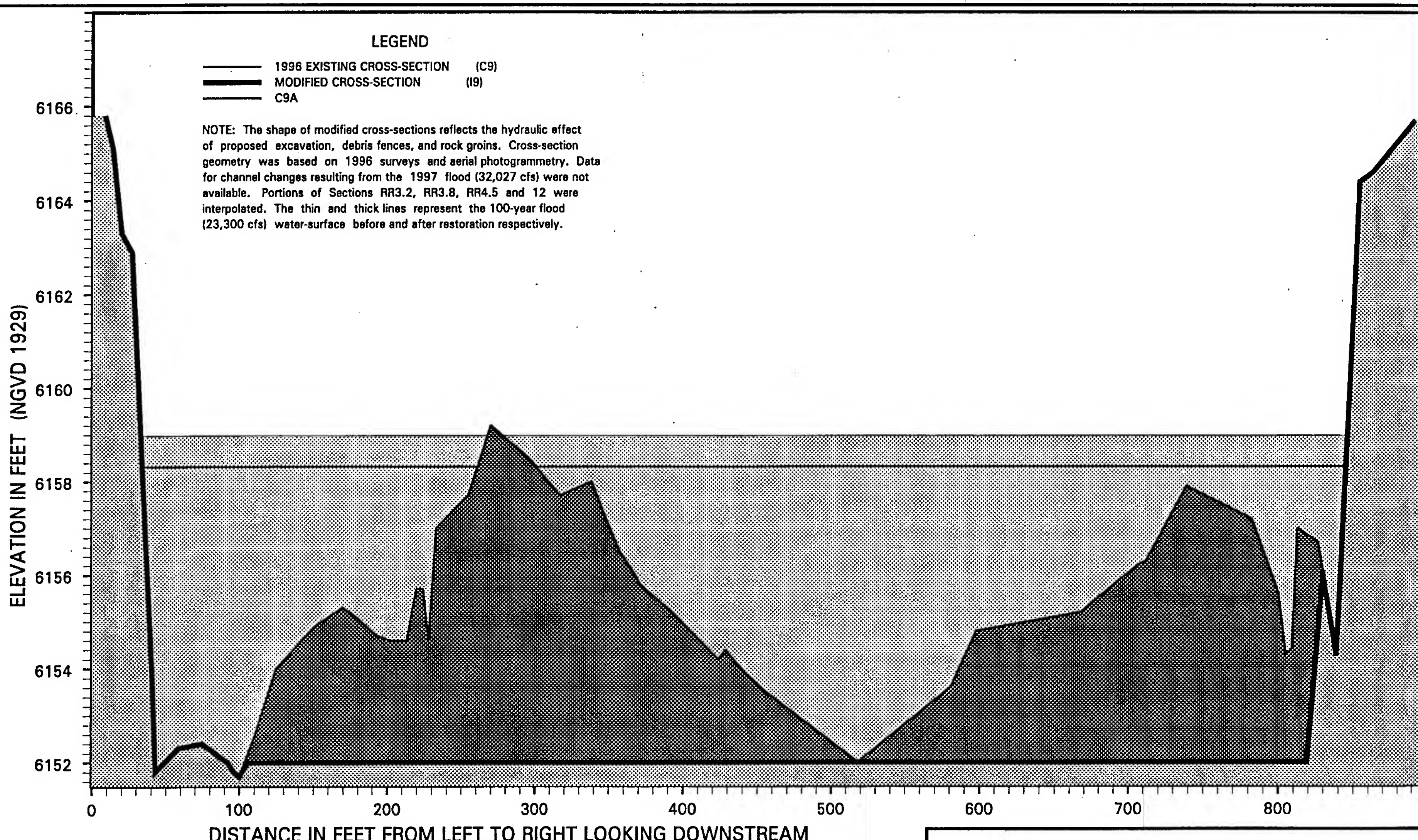
SNAKE RIVER AT JACKSON HOLE. AREA 9

100-YEAR FLOOD PROFILES
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 16 Mar 1998

PLATE A9-2

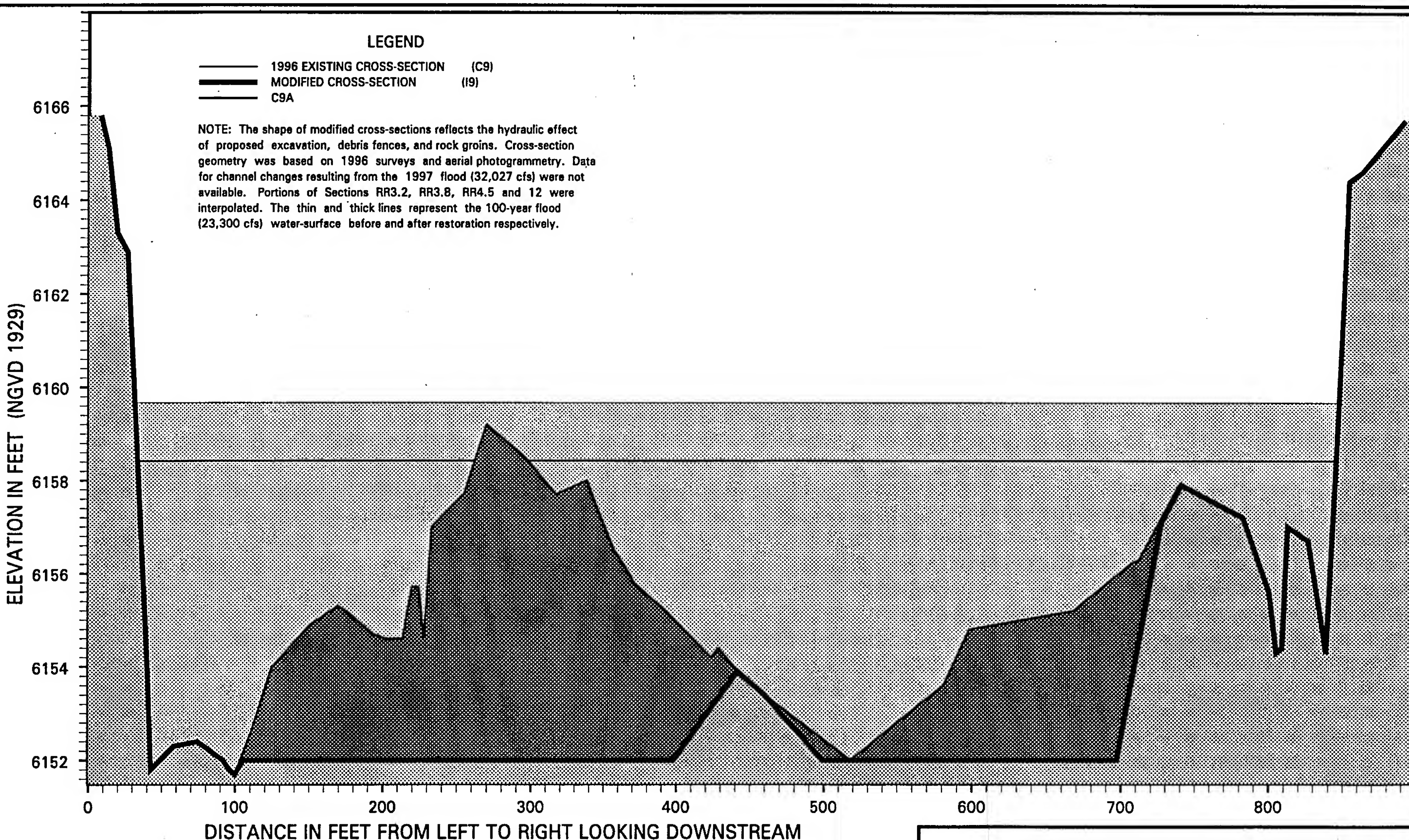


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 9: CROSS-SECTION 9.05
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 6 October 1998



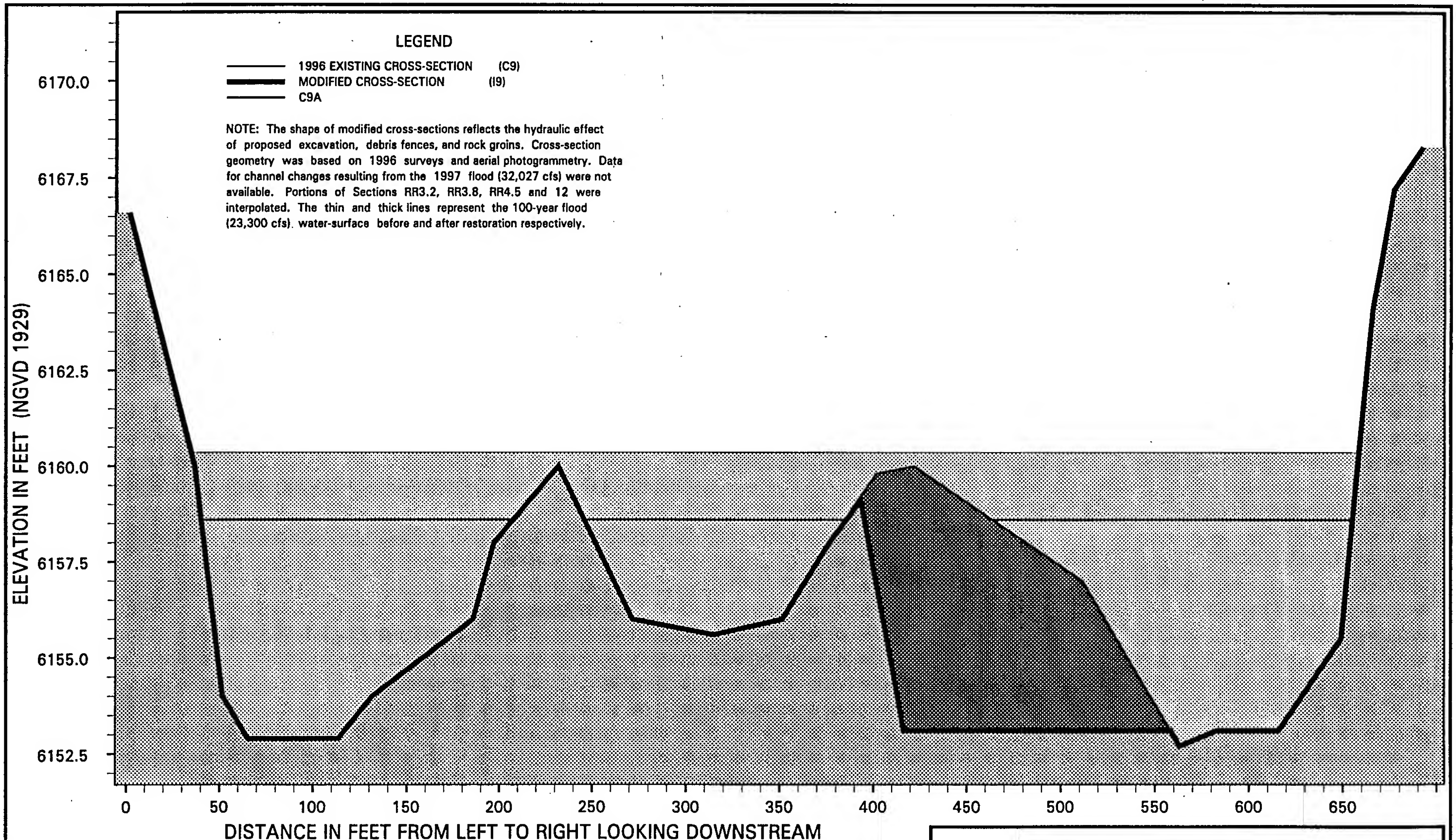
SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 9: CROSS-SECTION 9.30
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 6 October 1998

PLATE A9-4



SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 9: CROSS-SECTION 10.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 6 October 1998

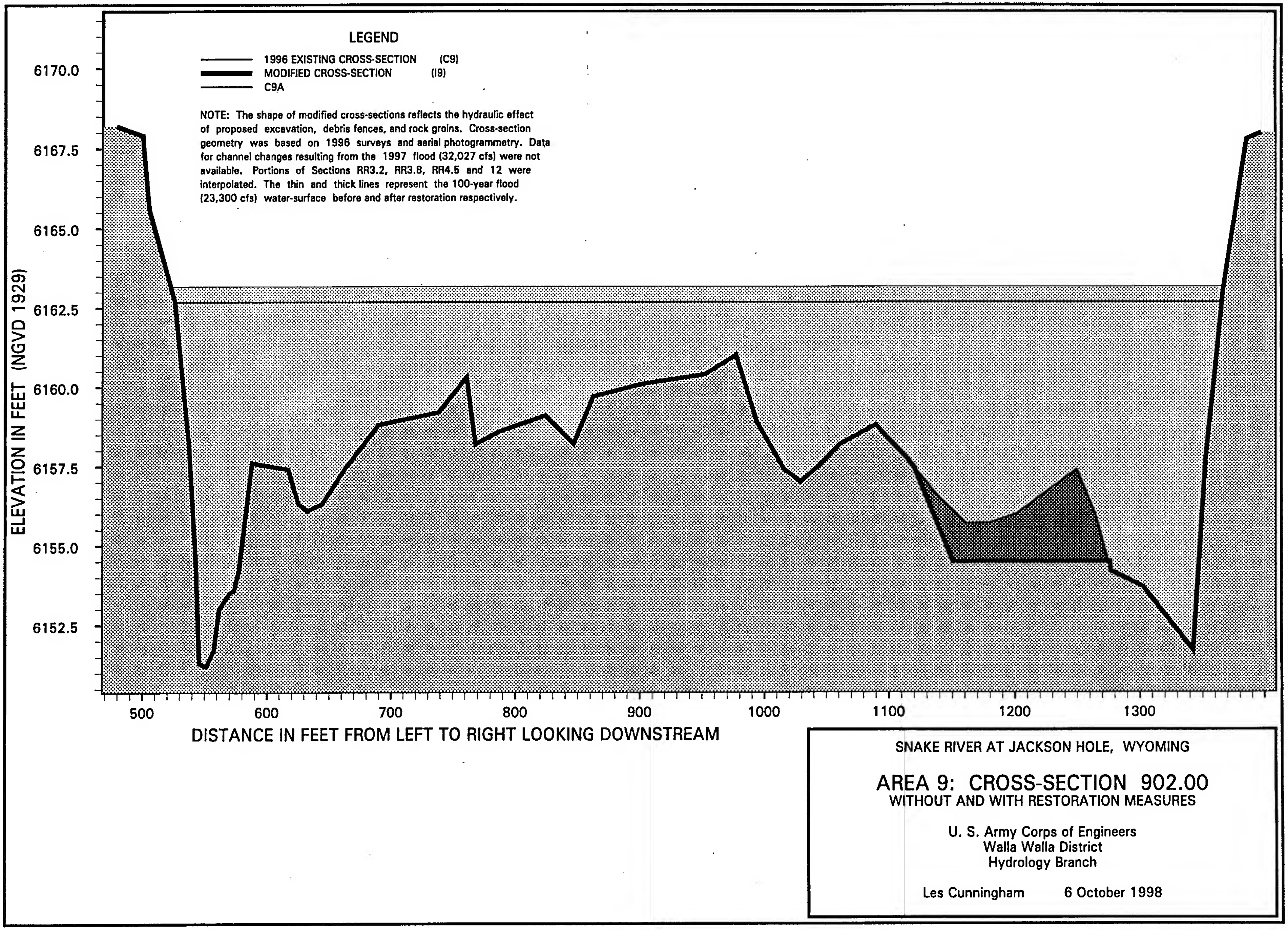
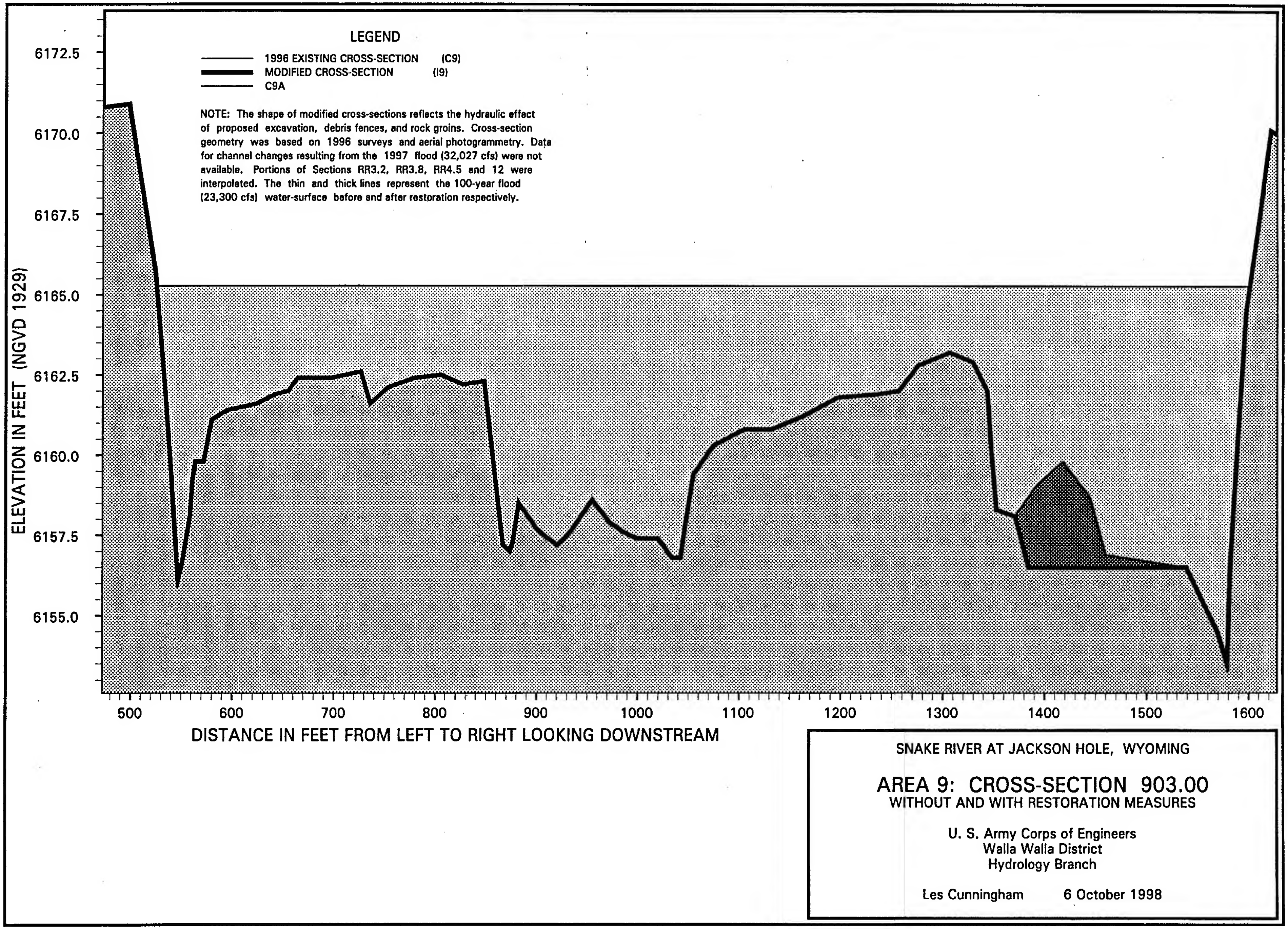
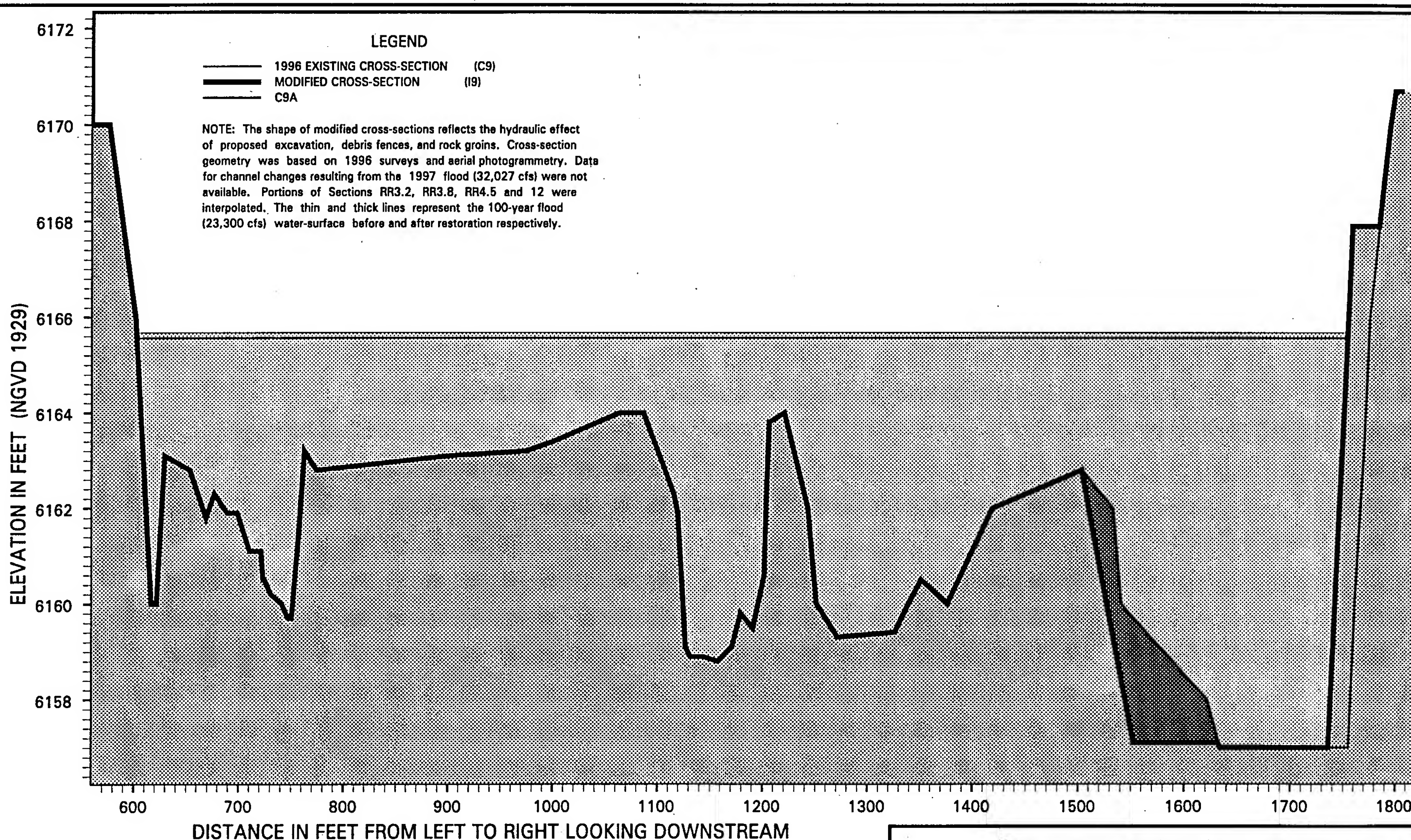

LEGEND
1996 EXISTING CROSS-SECTION (C9)
MODIFIED CROSS-SECTION (I9)
C9A
NOTE: The shape of modified cross-sections reflects the hydraulic effect of proposed excavation, debris fences, and rock groins. Cross-section geometry was based on 1996 surveys and aerial photogrammetry. Data for channel changes resulting from the 1997 flood (32,027 cfs) were not available. Portions of Sections RR3.2, RR3.8, RR4.5 and 12 were interpolated. The thin and thick lines represent the 100-year flood (23,300 cfs) water-surface before and after restoration respectively.
ELEVATION IN FEET (NGVD 1929)
6170.0
6167.5
6165.0
6162.5
6160.0
6157.5
6155.0
6152.5
500
600
700
800
900
1000
1100
1200
1300
DISTANCE IN FEET FROM LEFT TO RIGHT LOOKING DOWNSTREAM
SNAKE RIVER AT JACKSON HOLE, WYOMING
AREA 9: CROSS-SECTION 902.00
WITHOUT AND WITH RESTORATION MEASURES
U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch
Les Cunningham 6 October 1998

PLATE A9-6


LEGEND
1996 EXISTING CROSS-SECTION (C9)
MODIFIED CROSS-SECTION (I9)
C9A
NOTE: The shape of modified cross-sections reflects the hydraulic effect of proposed excavation, debris fences, and rock groins. Cross-section geometry was based on 1996 surveys and aerial photogrammetry. Data for channel changes resulting from the 1997 flood (32,027 cfs) were not available. Portions of Sections RR3.2, RR3.8, RR4.5 and 12 were interpolated. The thin and thick lines represent the 100-year flood (23,300 cfs) water-surface before and after restoration respectively.
ELEVATION IN FEET (NGVD 1929)
6172.5
6170.0
6167.5
6165.0
6162.5
6160.0
6157.5
6155.0
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
DISTANCE IN FEET FROM LEFT TO RIGHT LOOKING DOWNSTREAM
SNAKE RIVER AT JACKSON HOLE, WYOMING
AREA 9: CROSS-SECTION 903.00
WITHOUT AND WITH RESTORATION MEASURES
U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch
Les Cunningham
6 October 1998



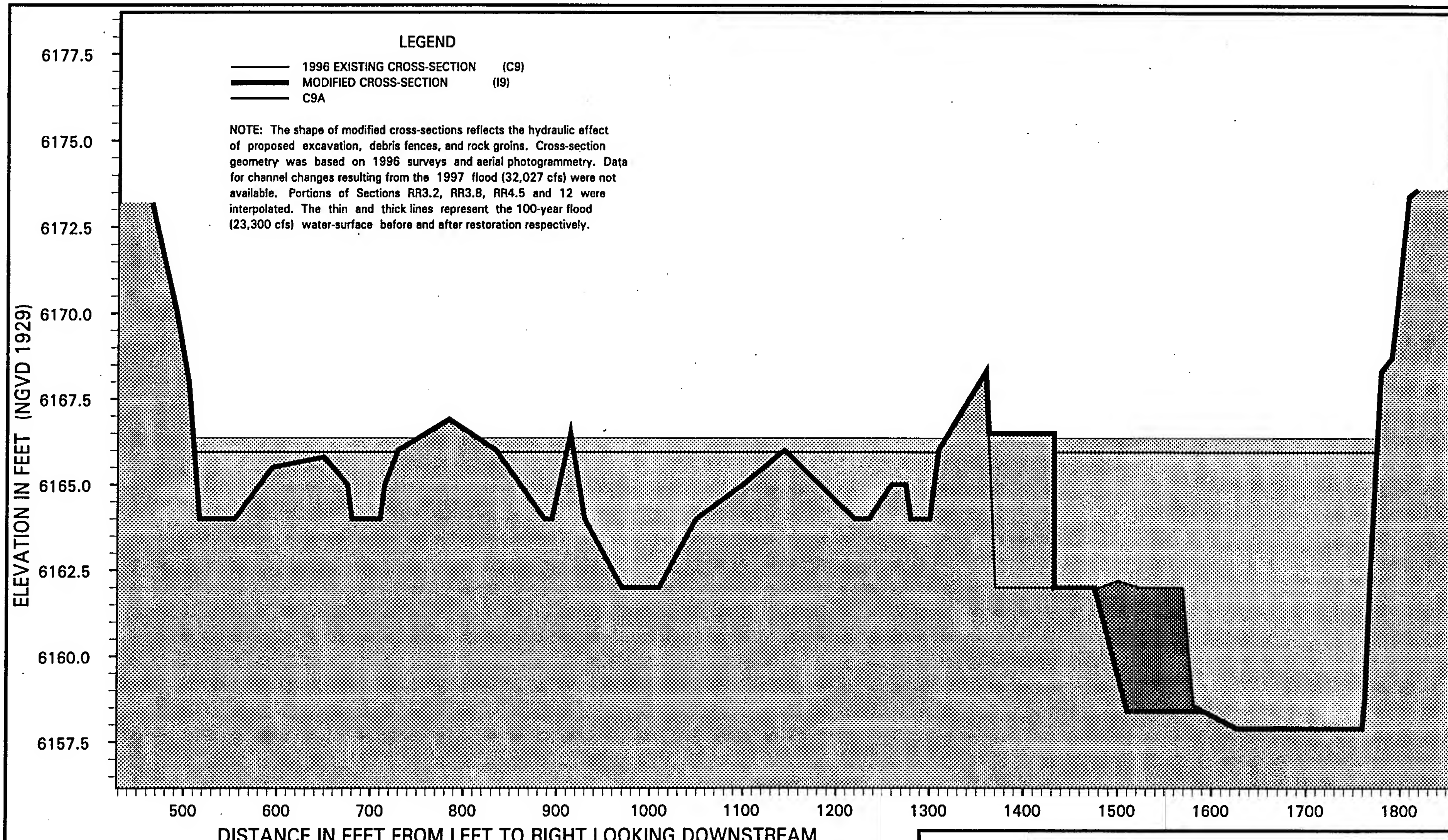
SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 9: CROSS-SECTION 903.20
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 6 October 1998

PLATE A9-8

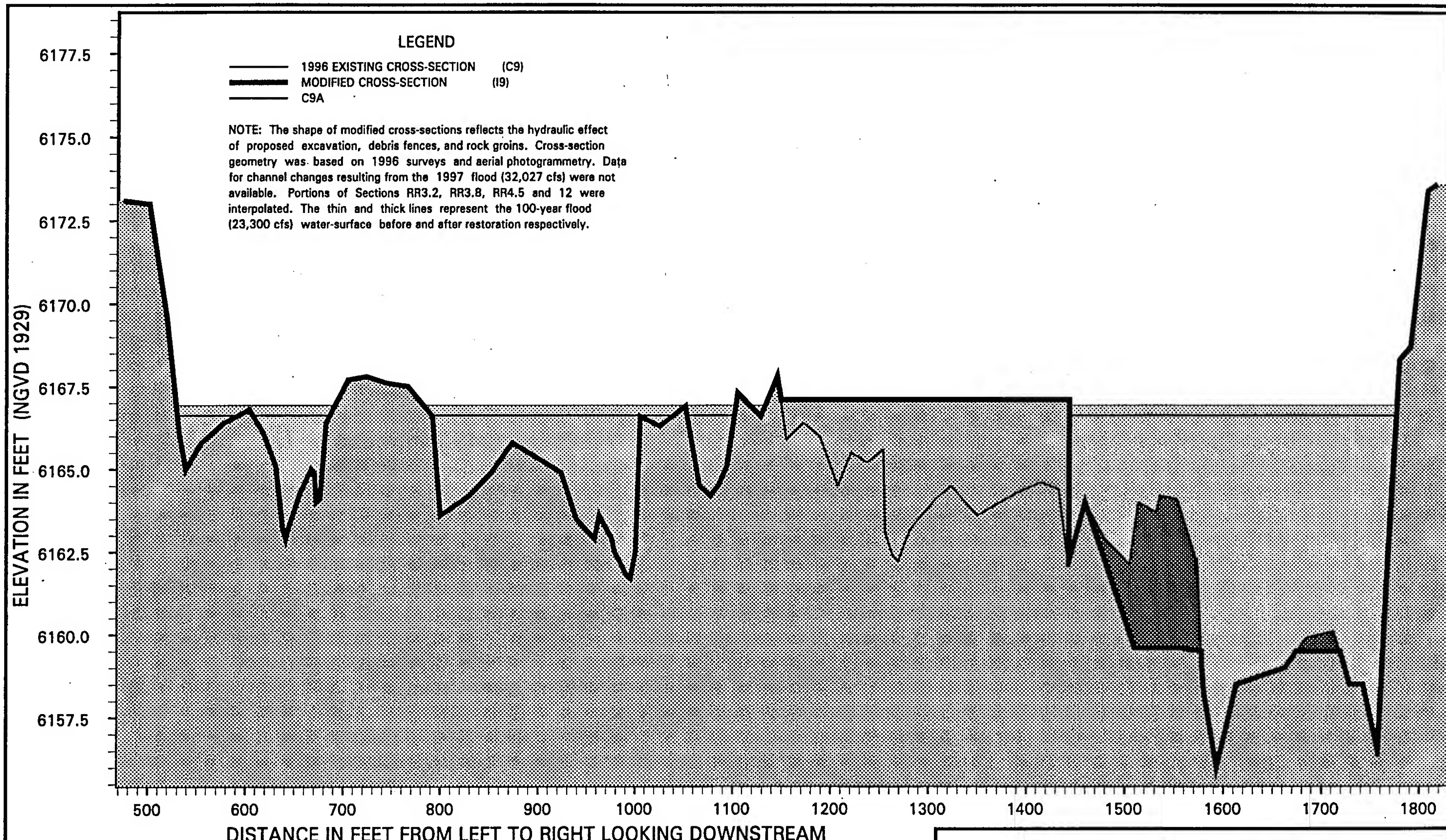


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 9: CROSS-SECTION 903.80
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 6 October 1998

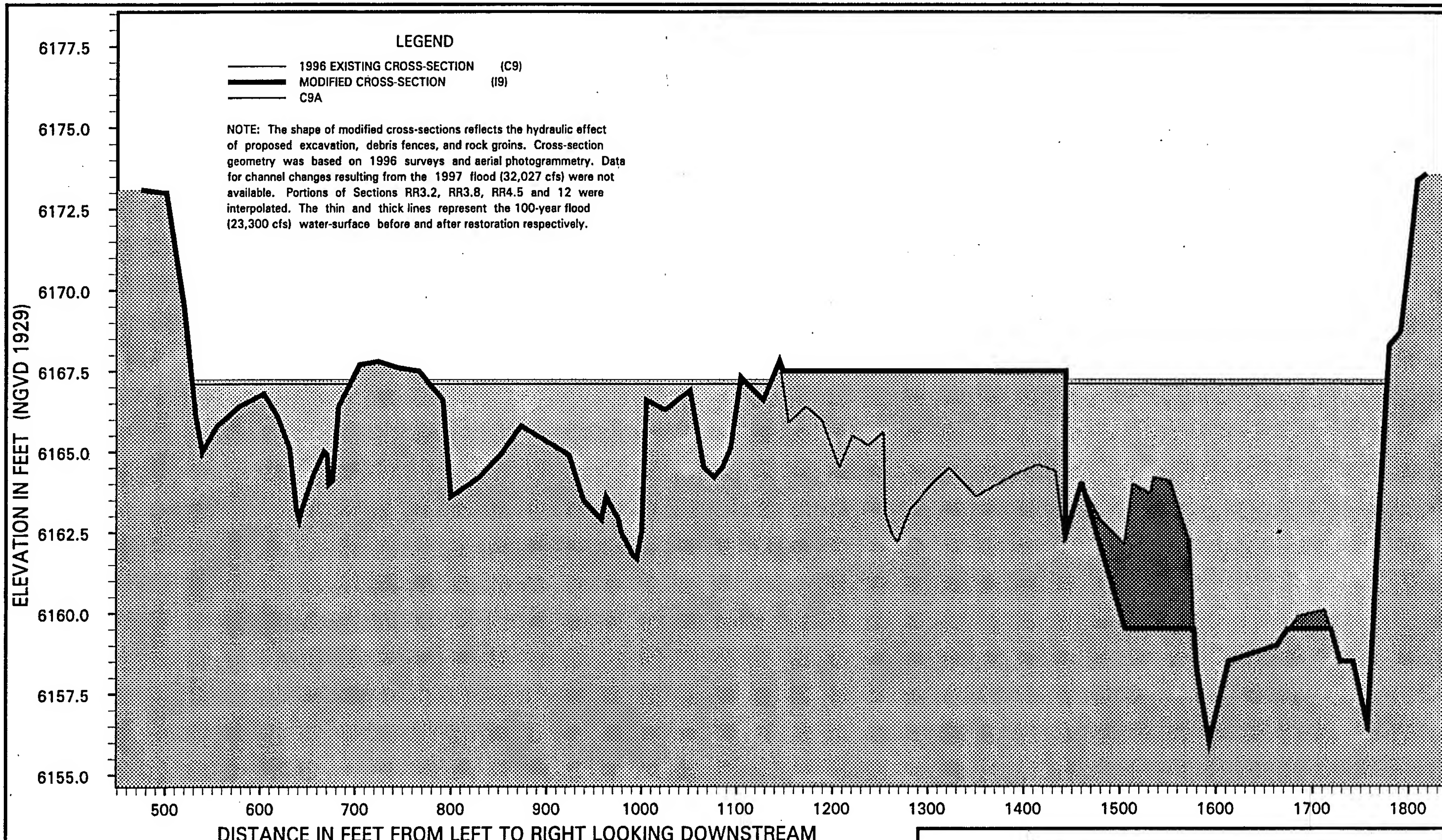


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 9: CROSS-SECTION 11.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 6 October 1998

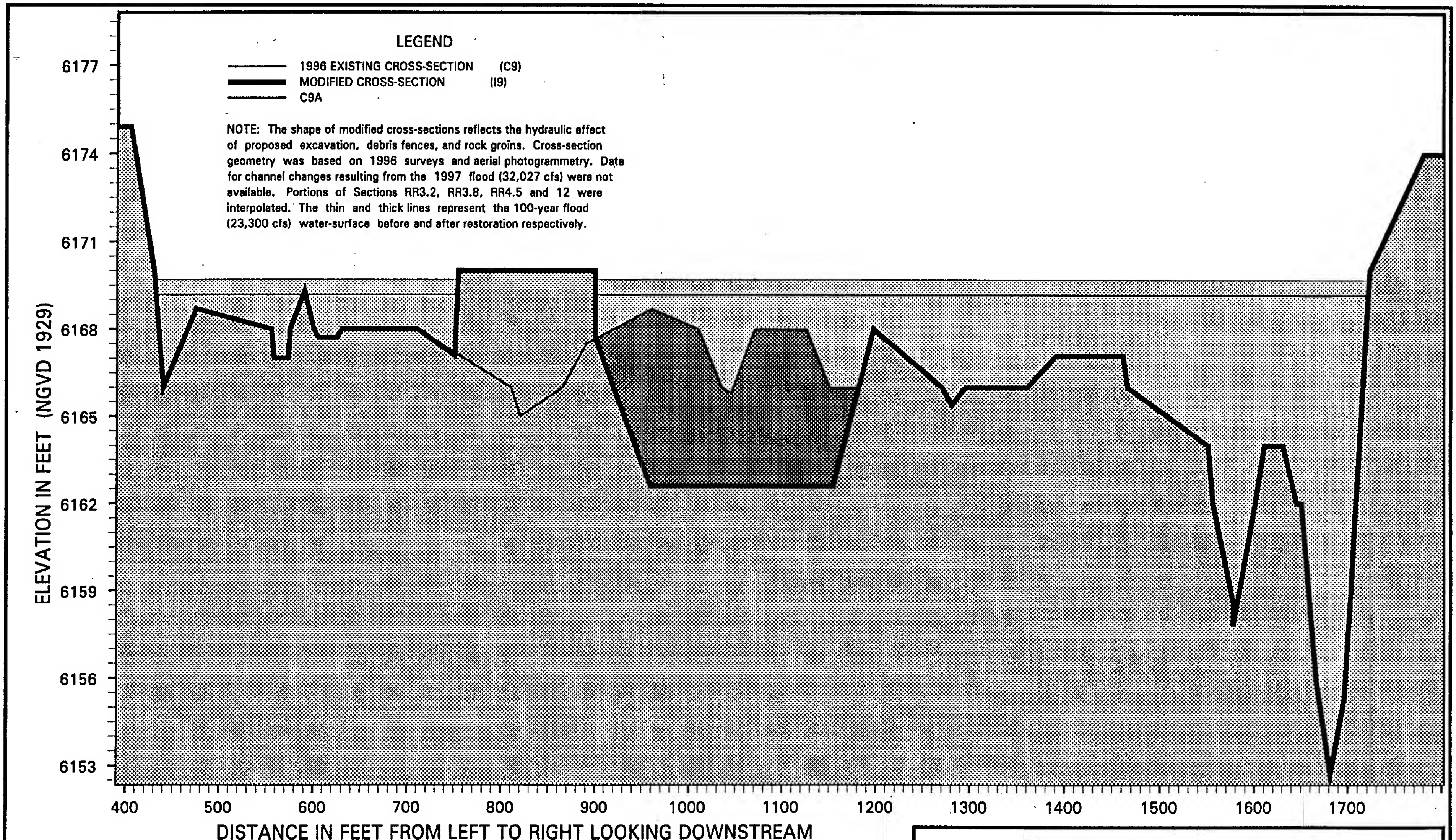


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 9: CROSS-SECTION 904.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham   6 October 1998

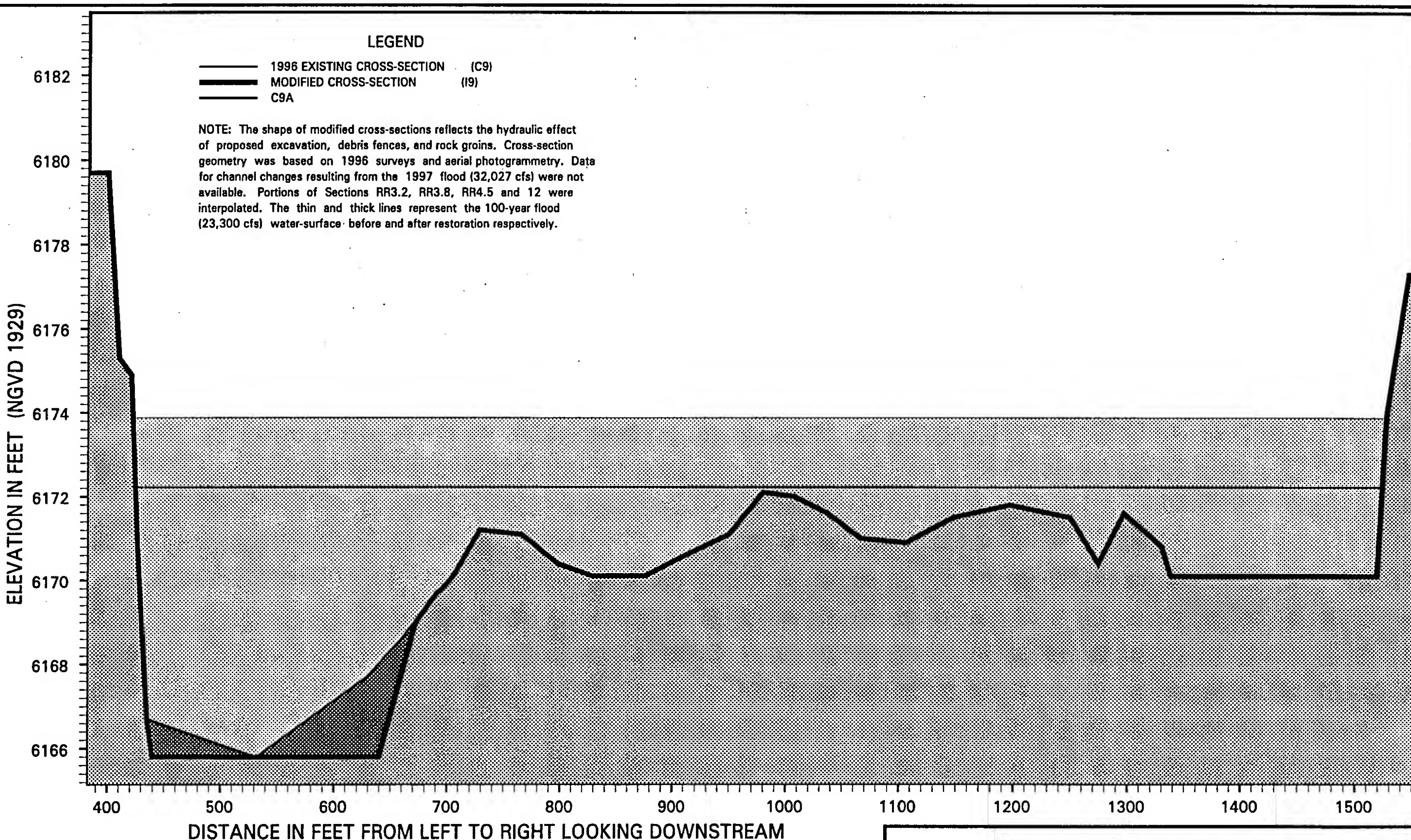


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 9: CROSS-SECTION 904.50
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 6 October 1998

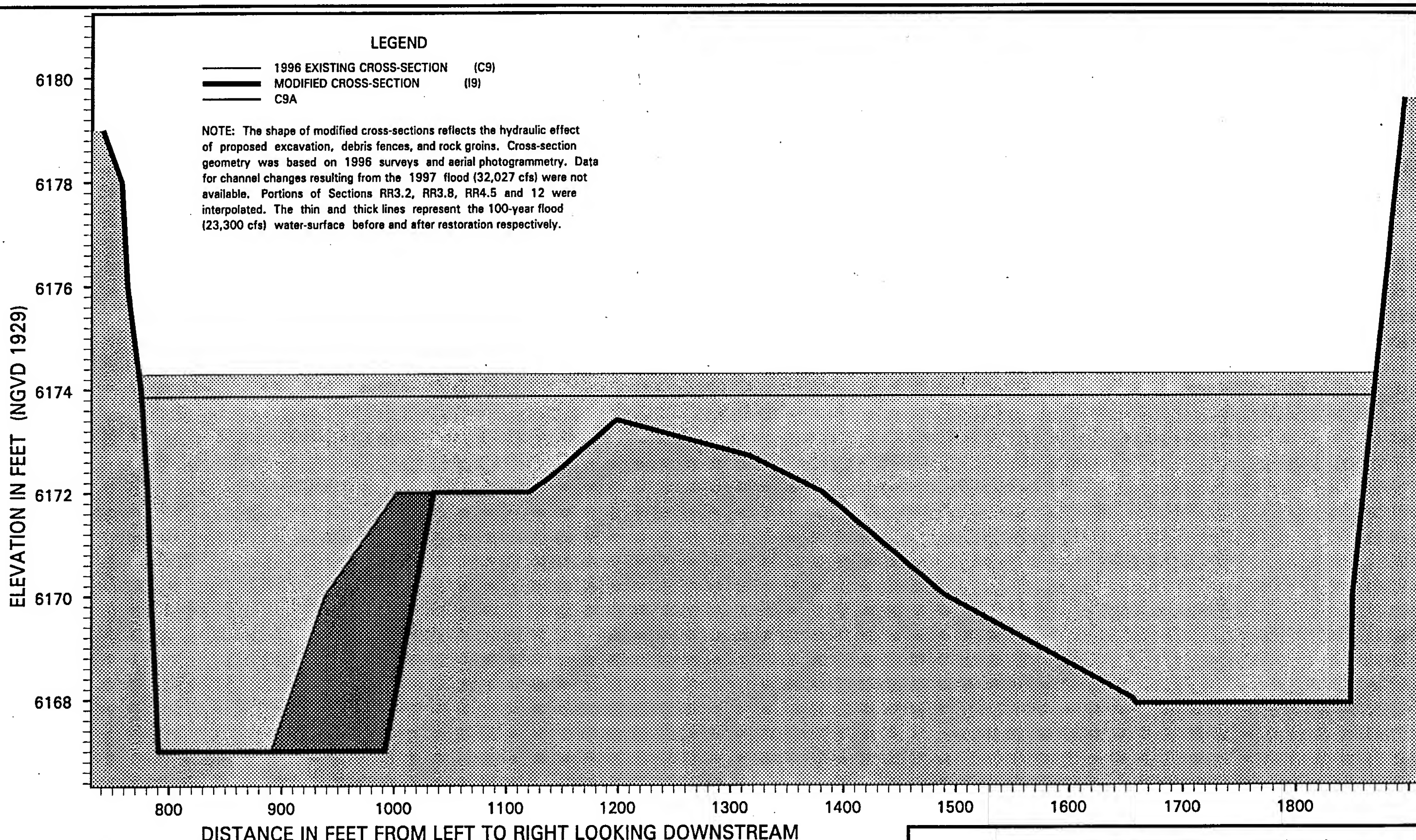


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 9: CROSS-SECTION 905.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 6 October 1998

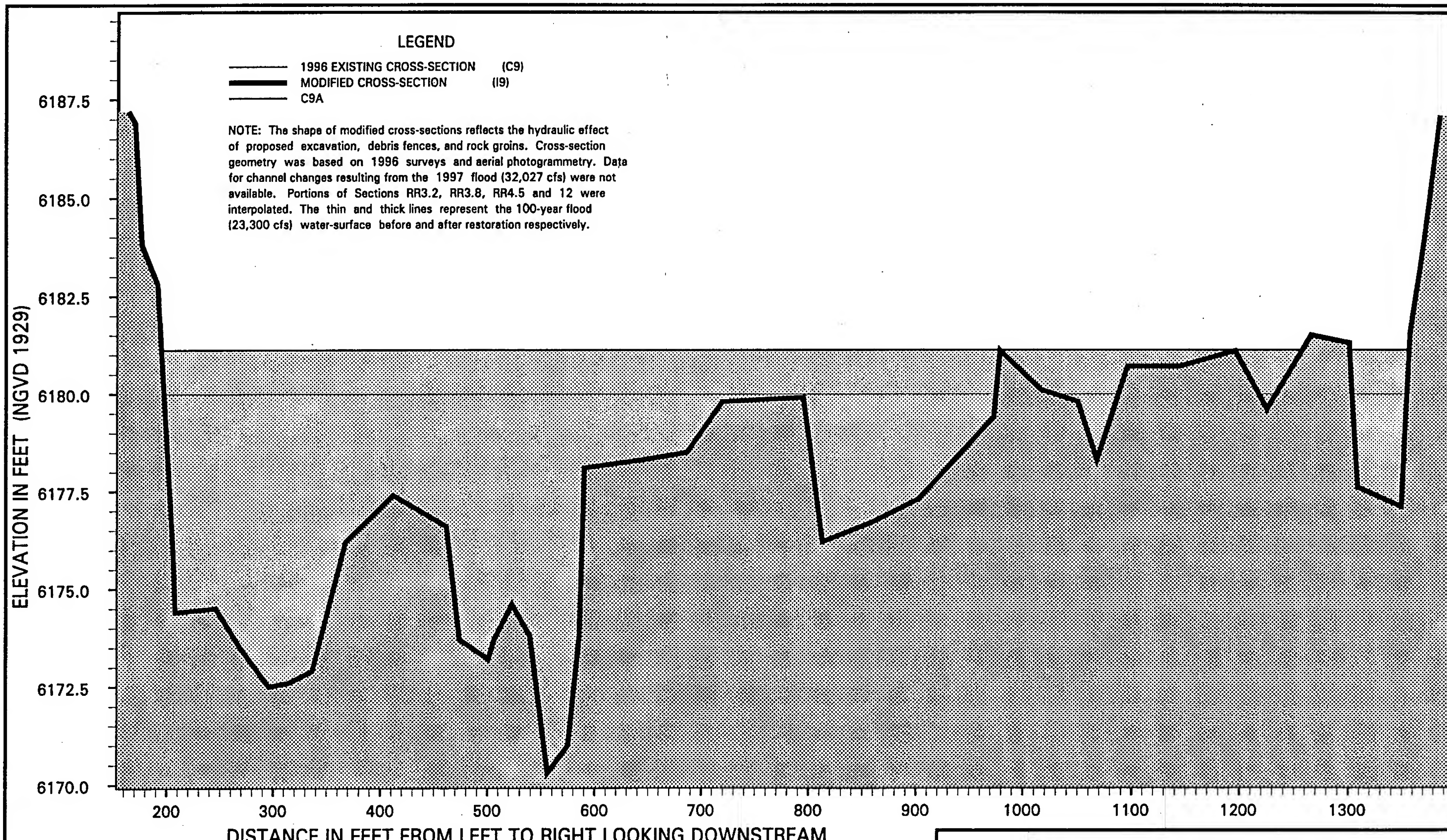


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 9: CROSS-SECTION 12.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 6 October 1998

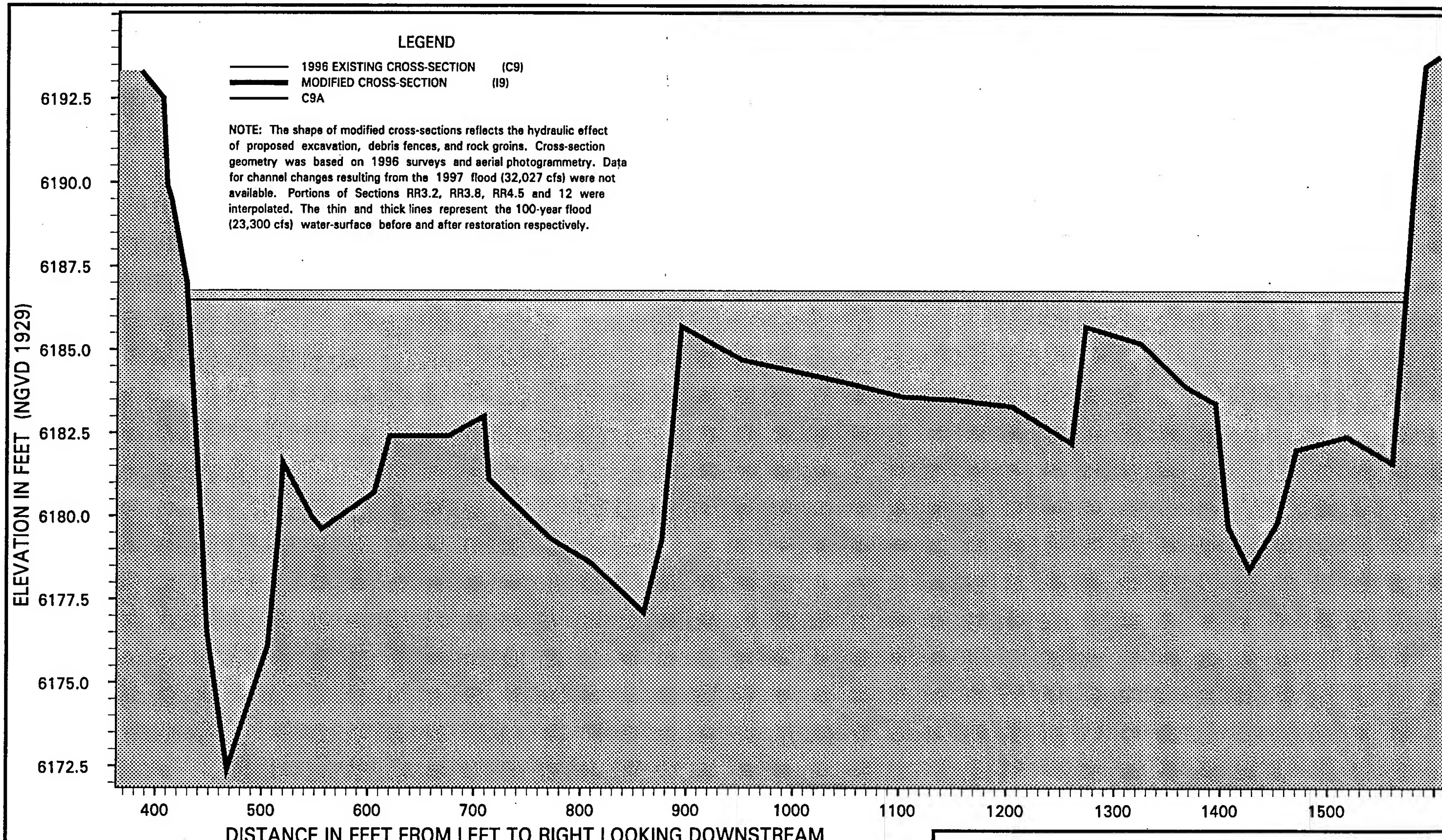


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 9: CROSS-SECTION 13.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 6 October 1998

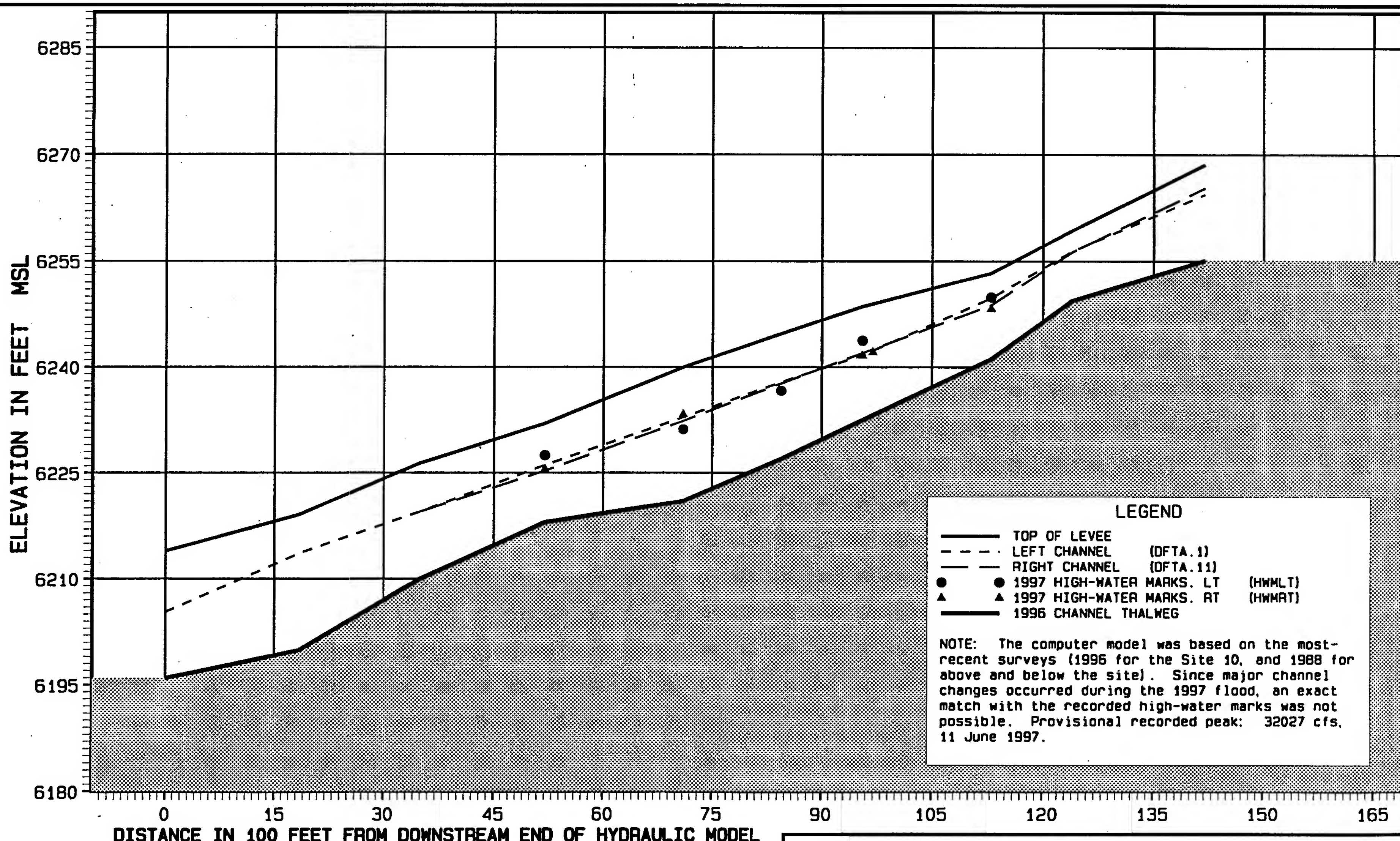


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 9: CROSS-SECTION 14.00
WITHOUT AND WITH RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

Les Cunningham 6 October 1998



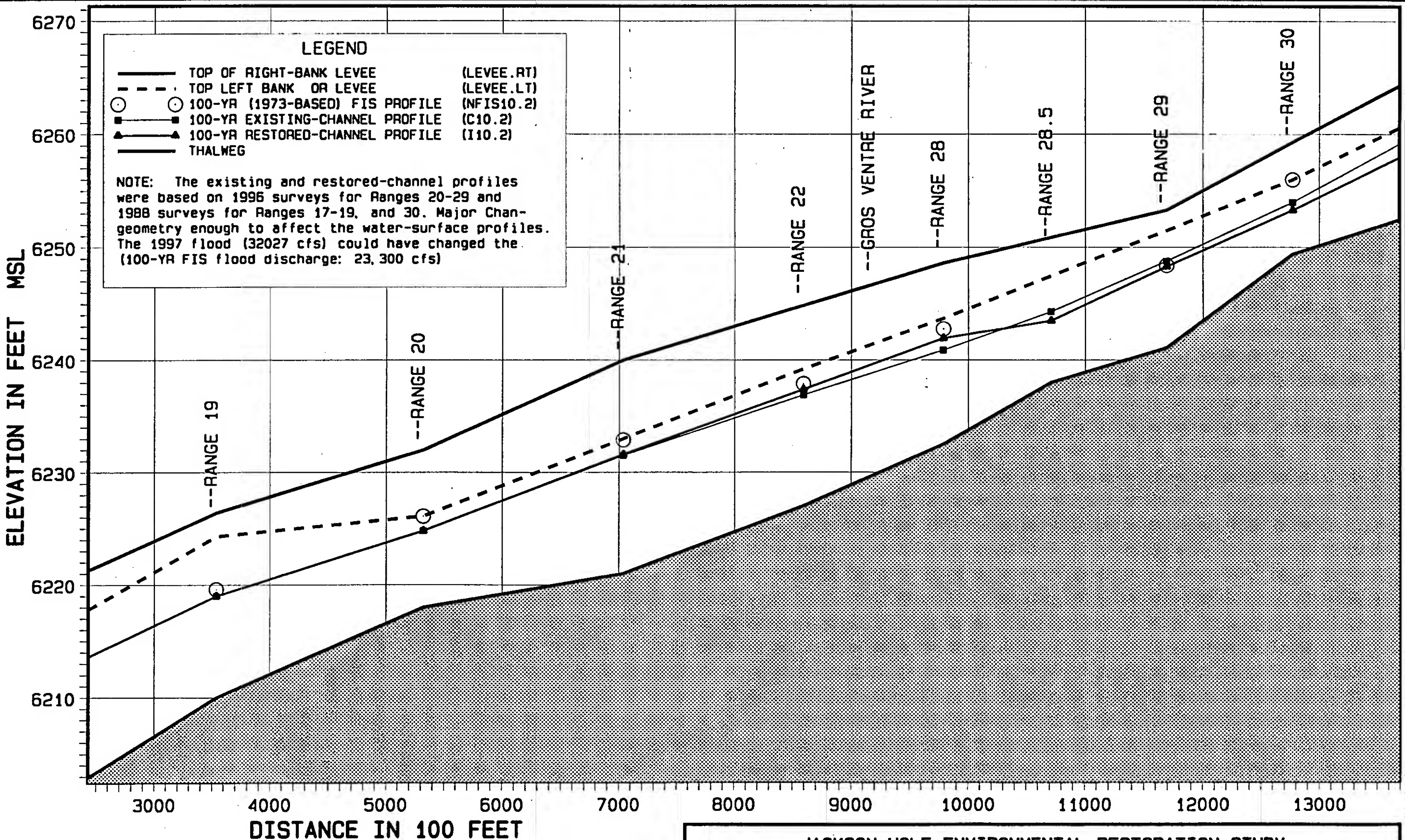
JACKSON HOLE ENVIRONMENTAL RESTORATION STUDY, SITE 10

SITE 10: HYDRAULIC MODEL CALIBRATION

1997 PEAK-FLOW PROFILES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

4 FEB 1998



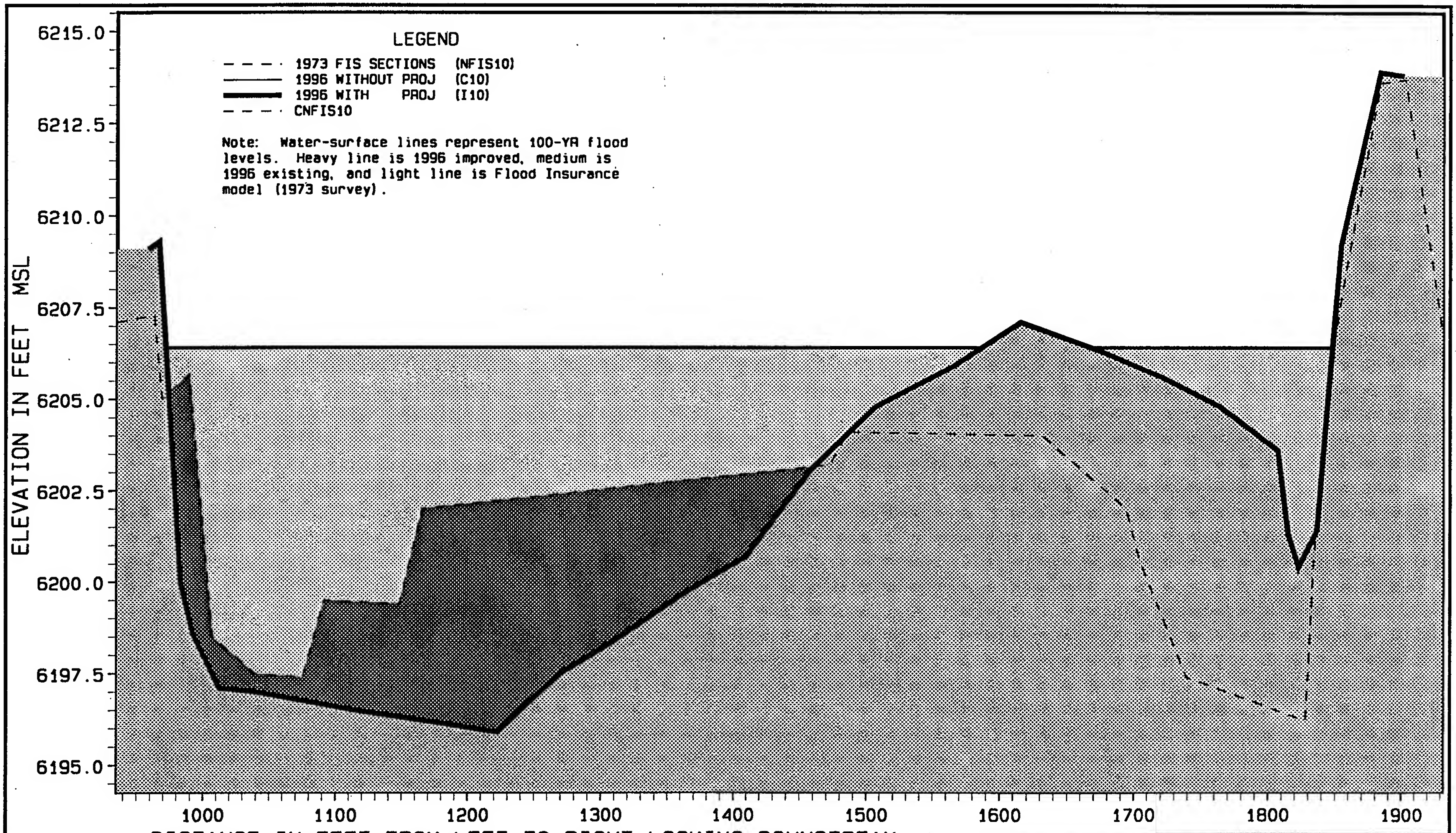
JACKSON HOLE ENVIRONMENTAL RESTORATION STUDY

AREA 10: 100-YEAR WATER-SURFACE PROFILES

COMPARISON: WITH AND WITHOUT RESTORATION MEASURES

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

30 September 1998



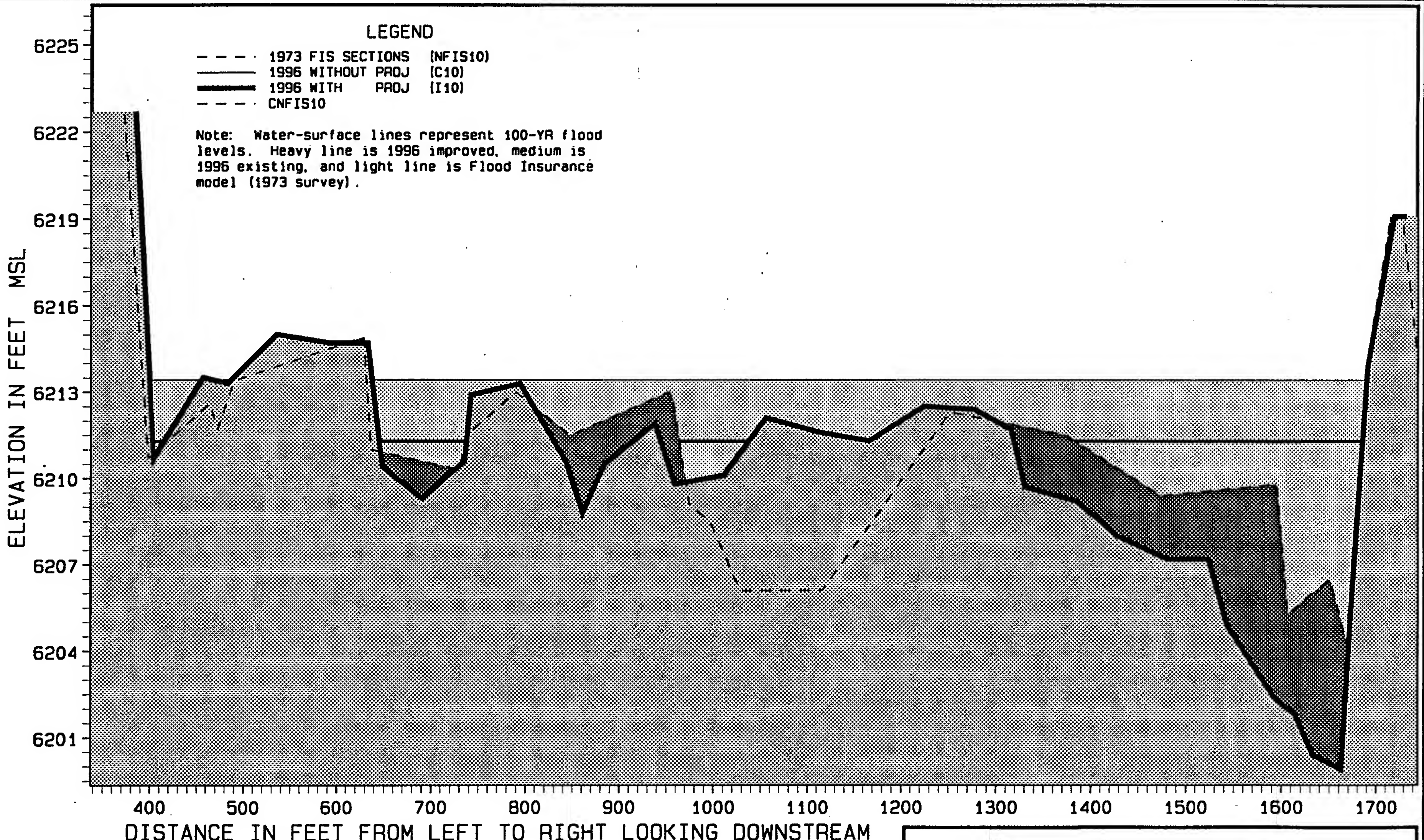
SNAKE RIVER AT JACKSON HOLE. WYOMING

AREA 10: CROSS-SECTION 17.00

(WITH AND WITHOUT RESTORATION MEASURES)

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

L. Cunningham 23 MAR 1998

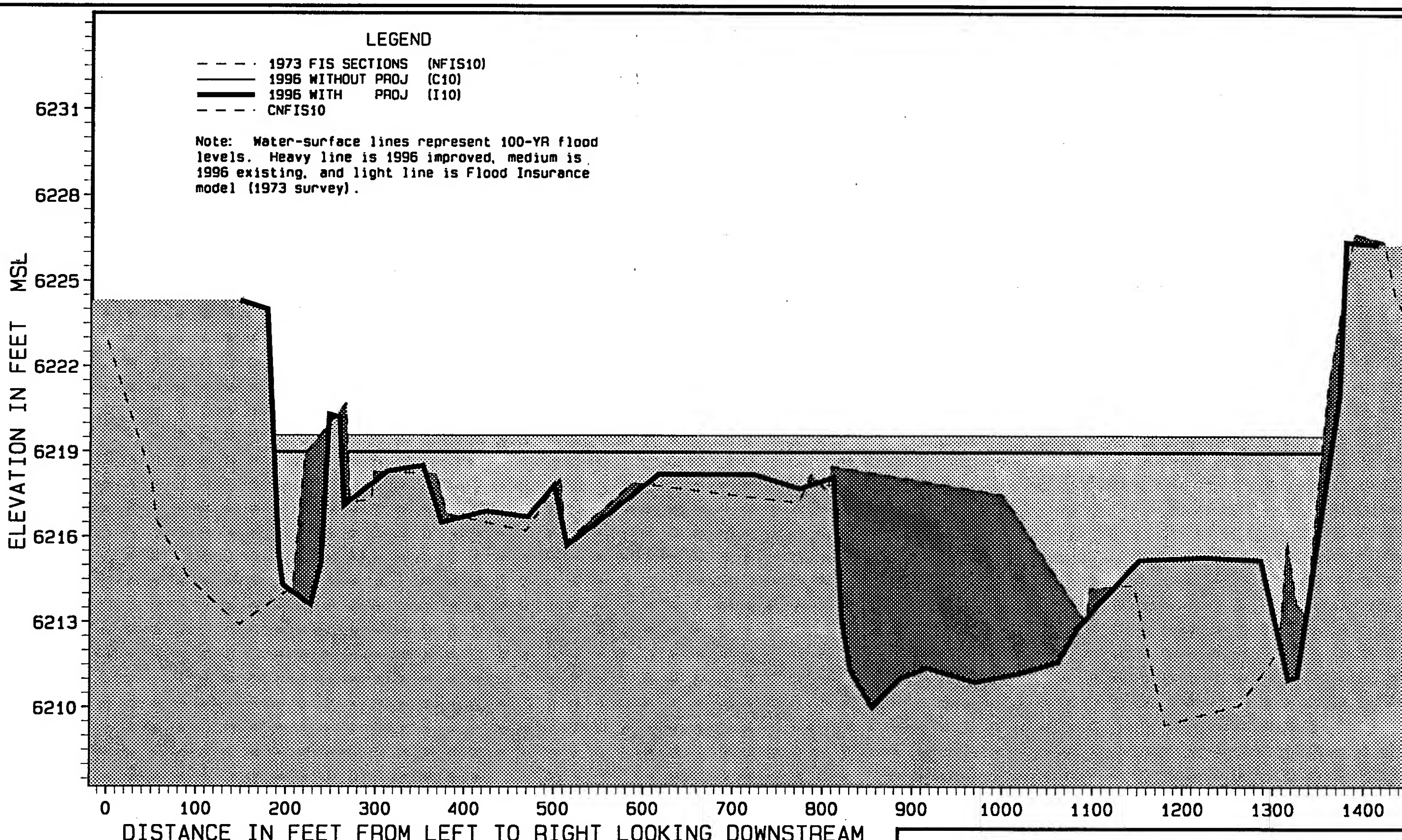


SNAKE RIVER AT JACKSON HOLE. WYOMING

AREA 10: CROSS-SECTION 18.00
(WITH AND WITHOUT RESTORATION MEASURES)

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

L. Cunningham 23 MAR 1998

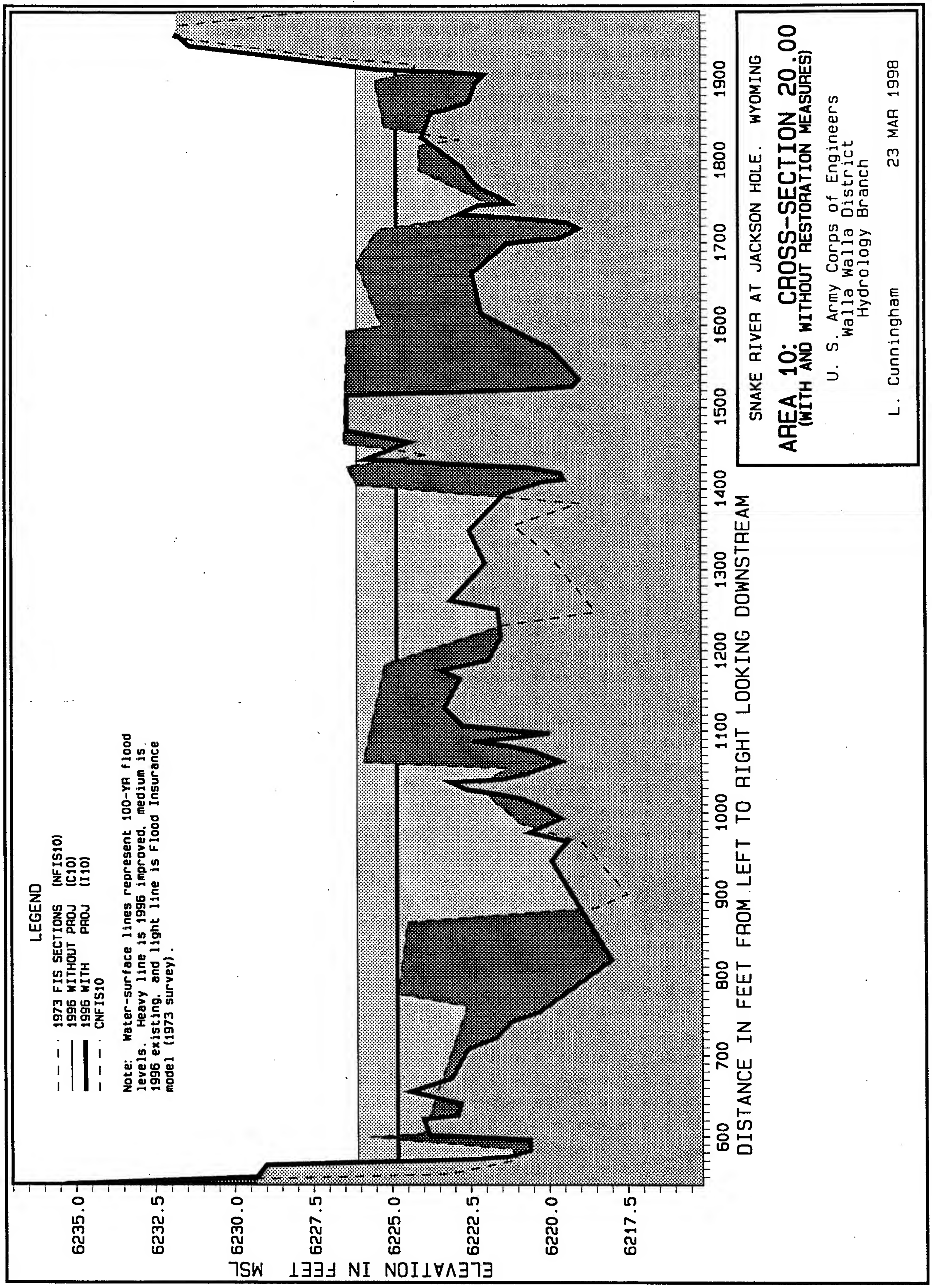


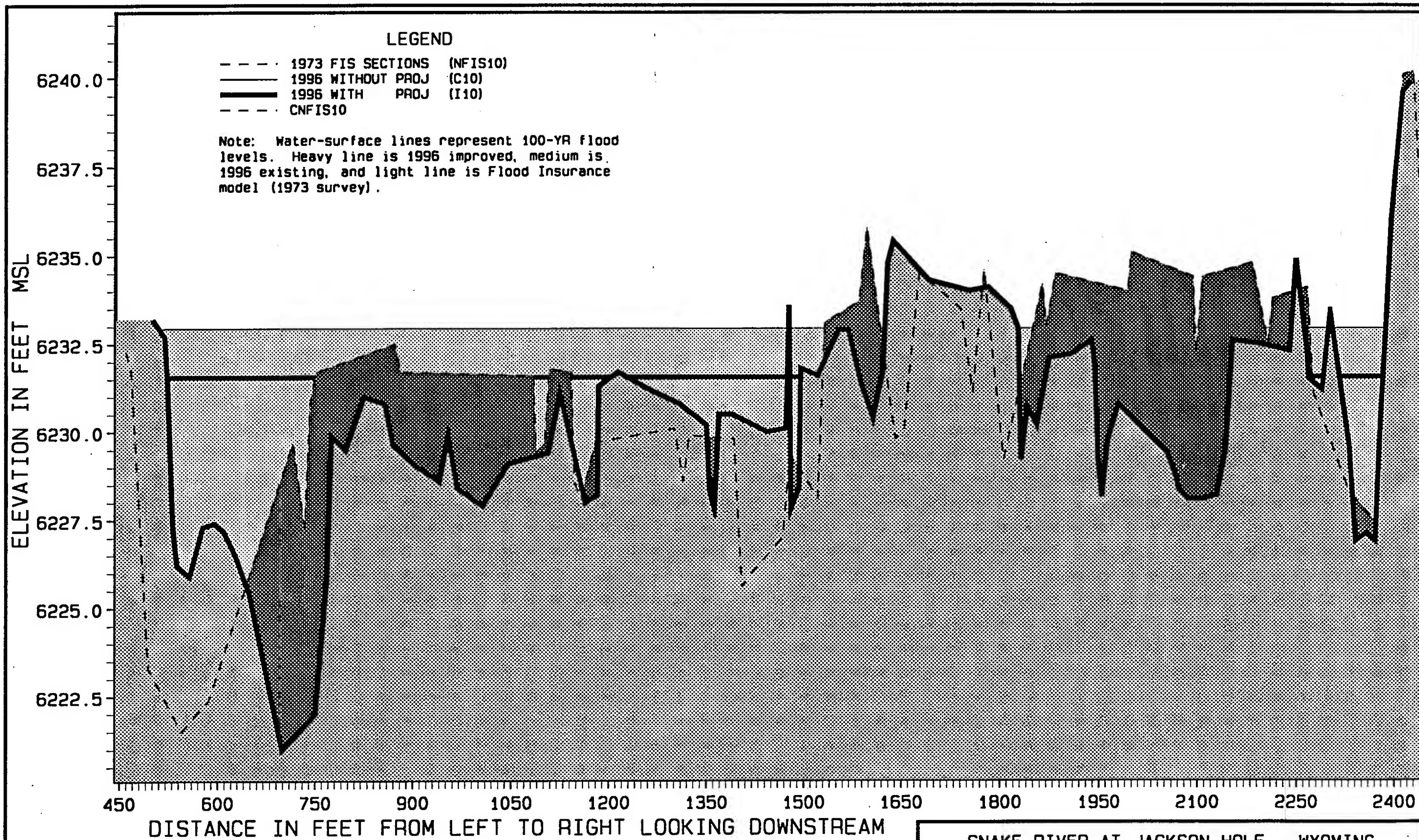
SNAKE RIVER AT JACKSON HOLE. WYOMING

AREA 10: CROSS-SECTION 19.00
(WITH AND WITHOUT RESTORATION MEASURES)

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

L. Cunningham 23 MAR 1998


SNAKE RIVER AT JACKSON HOLE. WYOMING
AREA 10: CROSS-SECTION 20.00
(WITH AND WITHOUT RESTORATION MEASURES)
U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch
L. Cunningham
23 MAR 1998
LEGEND
1973 FIS SECTIONS (NFIS10)
1996 WITHOUT PROJ (C10)
1996 WITH PROJ (I10)
CNFIS10
Note: Water-surface lines represent 100-YR flood levels. Heavy line is 1996 improved, medium is 1996 existing, and light line is Flood Insurance model (1973 survey).
ELEVATION IN FEET MSL
6235.0
6232.5
6230.0
6227.5
6225.0
6222.5
6220.0
6217.5
DISTANCE IN FEET FROM LEFT TO RIGHT LOOKING DOWNSTREAM
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900

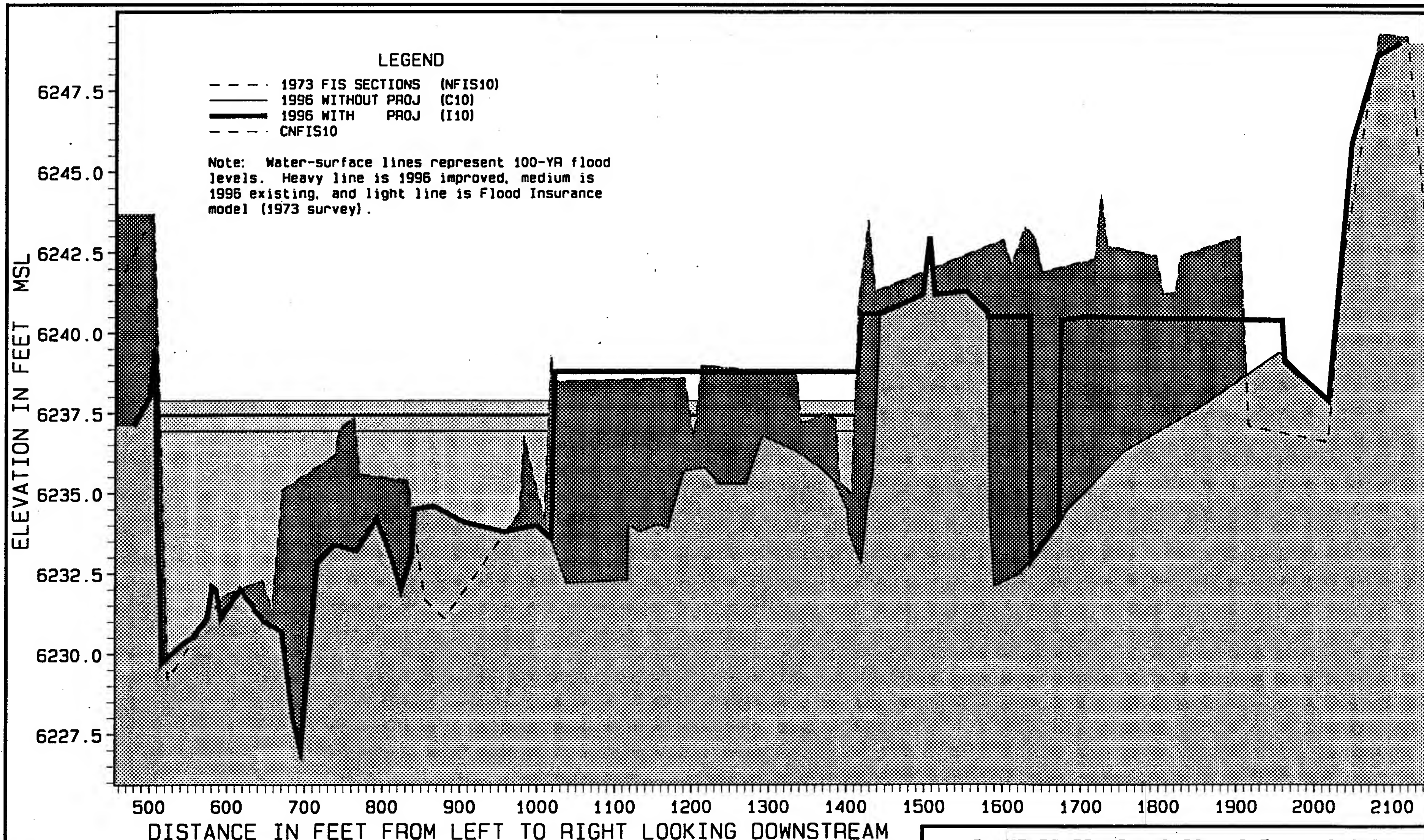


SNAKE RIVER AT JACKSON HOLE. WYOMING

AREA 10: CROSS-SECTION 21.00
(WITH AND WITHOUT RESTORATION MEASURES)

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

L. Cunningham 23 MAR 1998



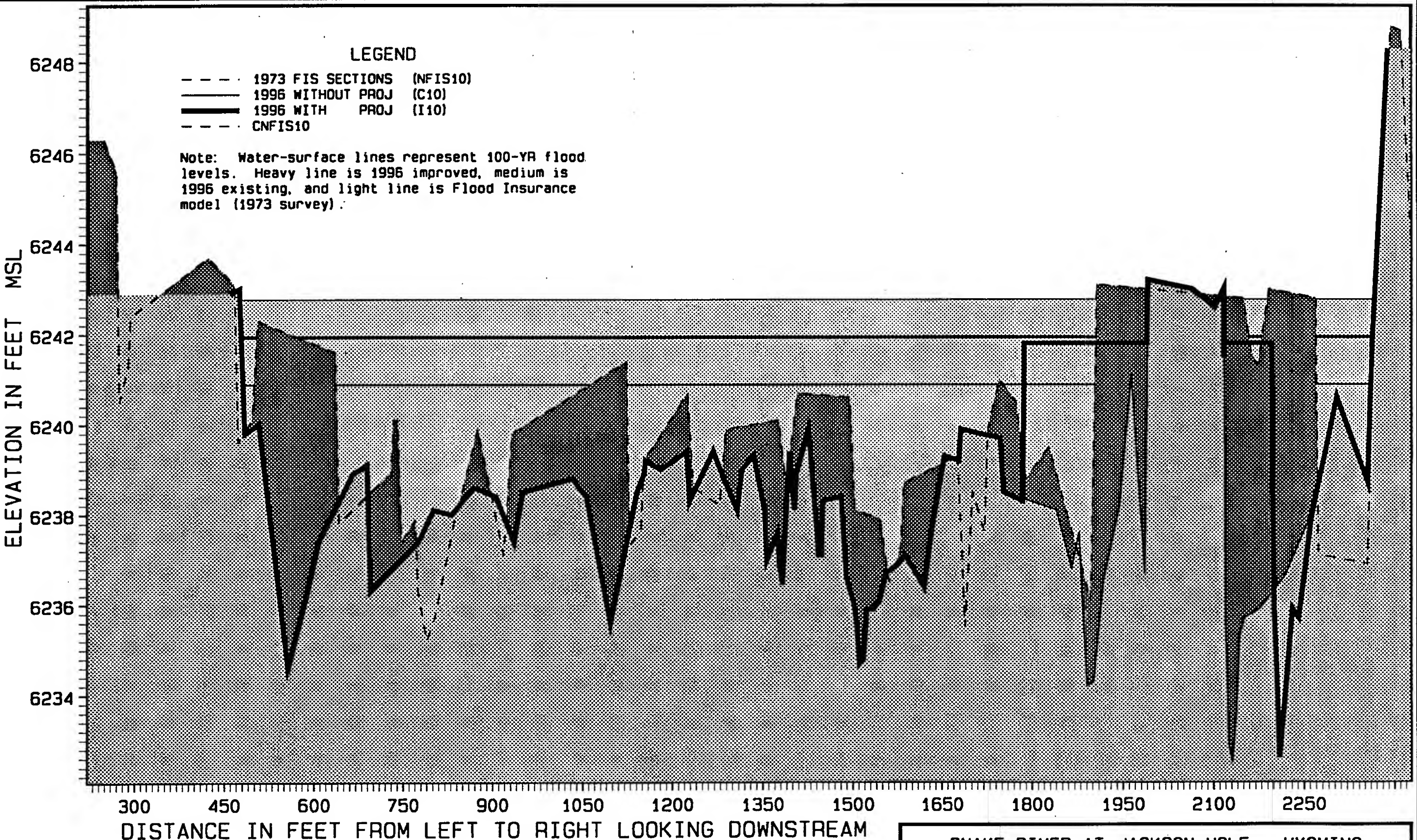
SNAKE RIVER AT JACKSON HOLE. WYOMING

AREA 10: CROSS-SECTION 22.00
(WITH AND WITHOUT RESTORATION MEASURES)

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

L. Cunningham 23 MAR 1998

PLATE A10-8

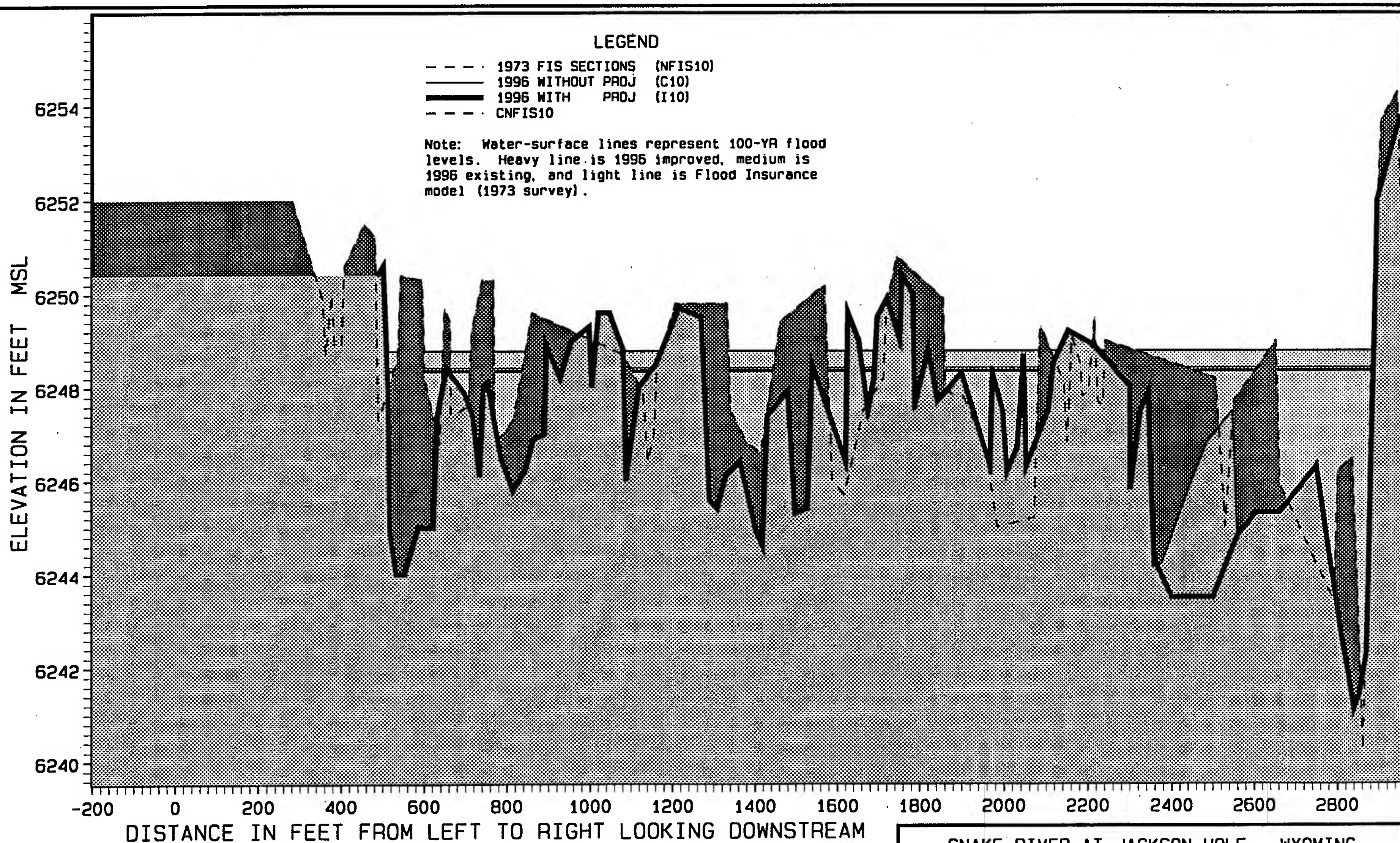


SNAKE RIVER AT JACKSON HOLE. WYOMING

AREA 10: CROSS-SECTION 28.00
(WITH AND WITHOUT RESTORATION MEASURES)

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

L. Cunningham 23 MAR 1998

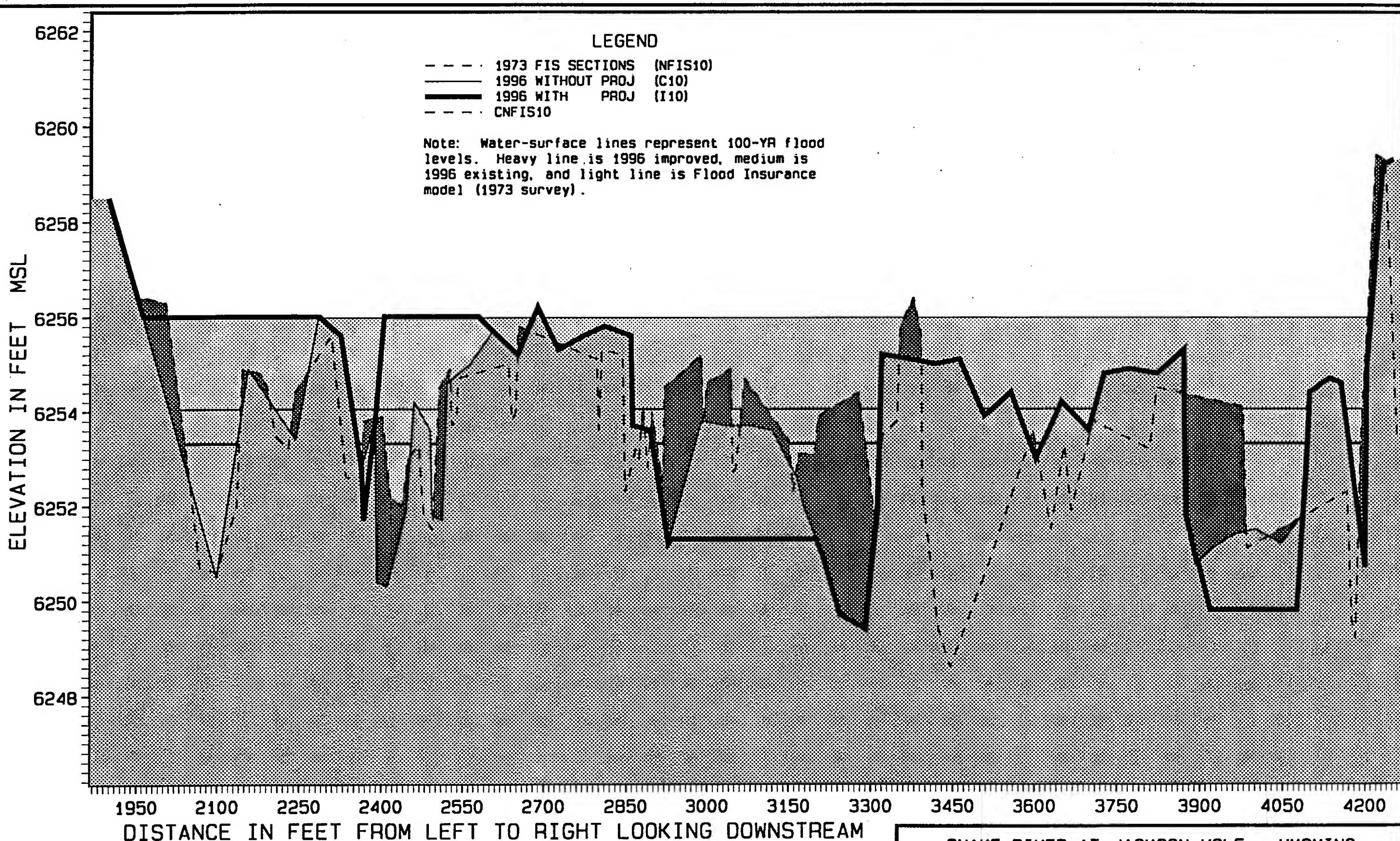


SNAKE RIVER AT JACKSON HOLE, WYOMING

AREA 10: CROSS-SECTION 29.00
(WITH AND WITHOUT RESTORATION MEASURES)

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

L. Cunningham 23 MAR 1998



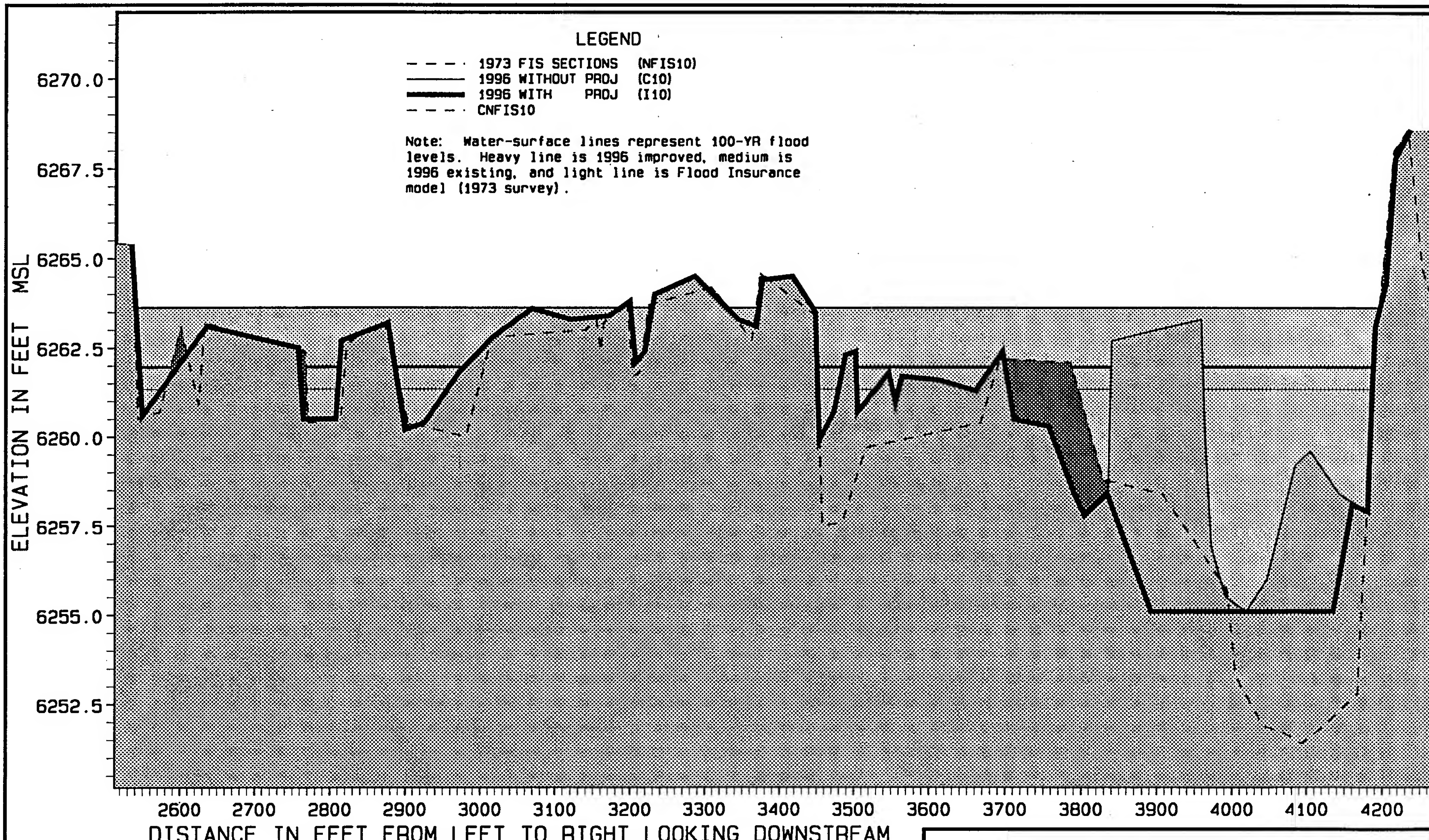
SNAKE RIVER AT JACKSON HOLE. WYOMING

AREA 10: CROSS-SECTION 30.00
(WITH AND WITHOUT RESTORATION MEASURES)

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

L. Cunningham 23 MAR 1998

PLATE A10-11



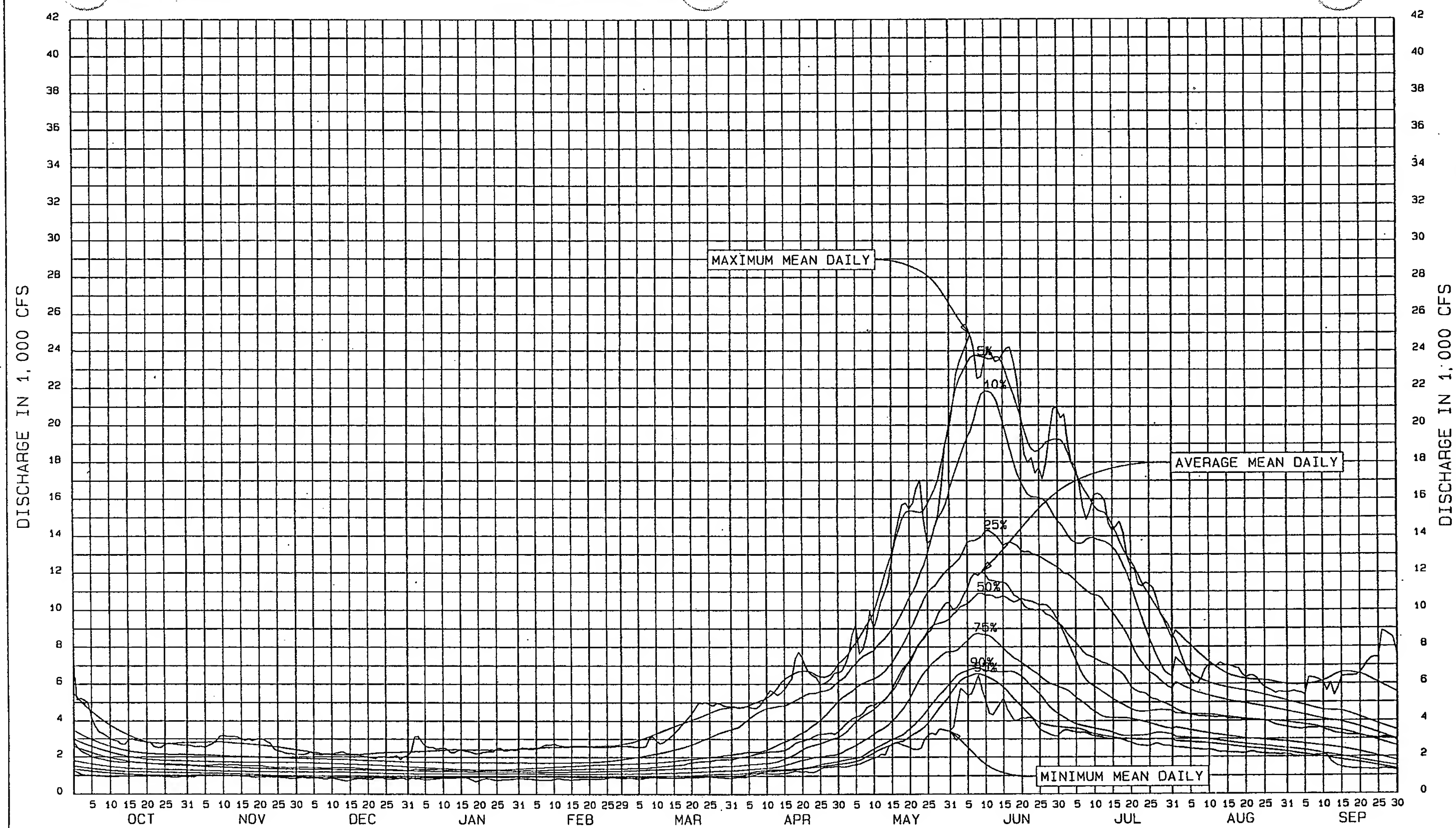
SNAKE RIVER AT JACKSON HOLE. WYOMING

AREA 10: CROSS-SECTION 31.00

(WITH AND WITHOUT RESTORATION MEASURES)

U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch

L. Cunningham 23 MAR 1998



NOTE:

1. PERIOD OF RECORD IS DEC 1975 THROUGH MAY 1997

SNAKE RIVER WYOMING
BELOW FLAT CREEK

SUMMARY HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA - HYDROLOGY BRANCH

MAXSON SEPTEMBER 1997

CHART 1

Notes:

1. The Gros Ventre River near Kelly, Wyoming has a drainage area of 622 square miles. The period of record at this location is from 1918, 1945 through 1958.

2. The Annual Peak Discharge Frequency curve was developed using a regional frequency analysis to extend the record of the Gros Ventre River near Kelly to a period of 1904 through 1978. The regional analysis used the following gaging stations.

Station	Drainage Area (square miles)	Period of record
Snake River at Moran, Wyoming	807	1904-1974
Pacific Creek near Moran, Wy	169	1918, 1945-1975
Buffalo Fork near Moran, Wy	323	1918, 1945-1960 1966-1978
Snake River near Jackson, Wy	2627	1904-1968

Flood analysis was conducted on the stations to obtain an unregulated flow at each site.

3. The regional frequency analysis exetended the Gros Ventre near Kelly to a period of record from 1904 through 1978.

4. Frequency statistics for this station were computed using the "Water Resources Council Guidelines," Bulletin 17B, dated September 1981. Confidence limits were computed using the record data and the frequency curve was computed using the extended record.

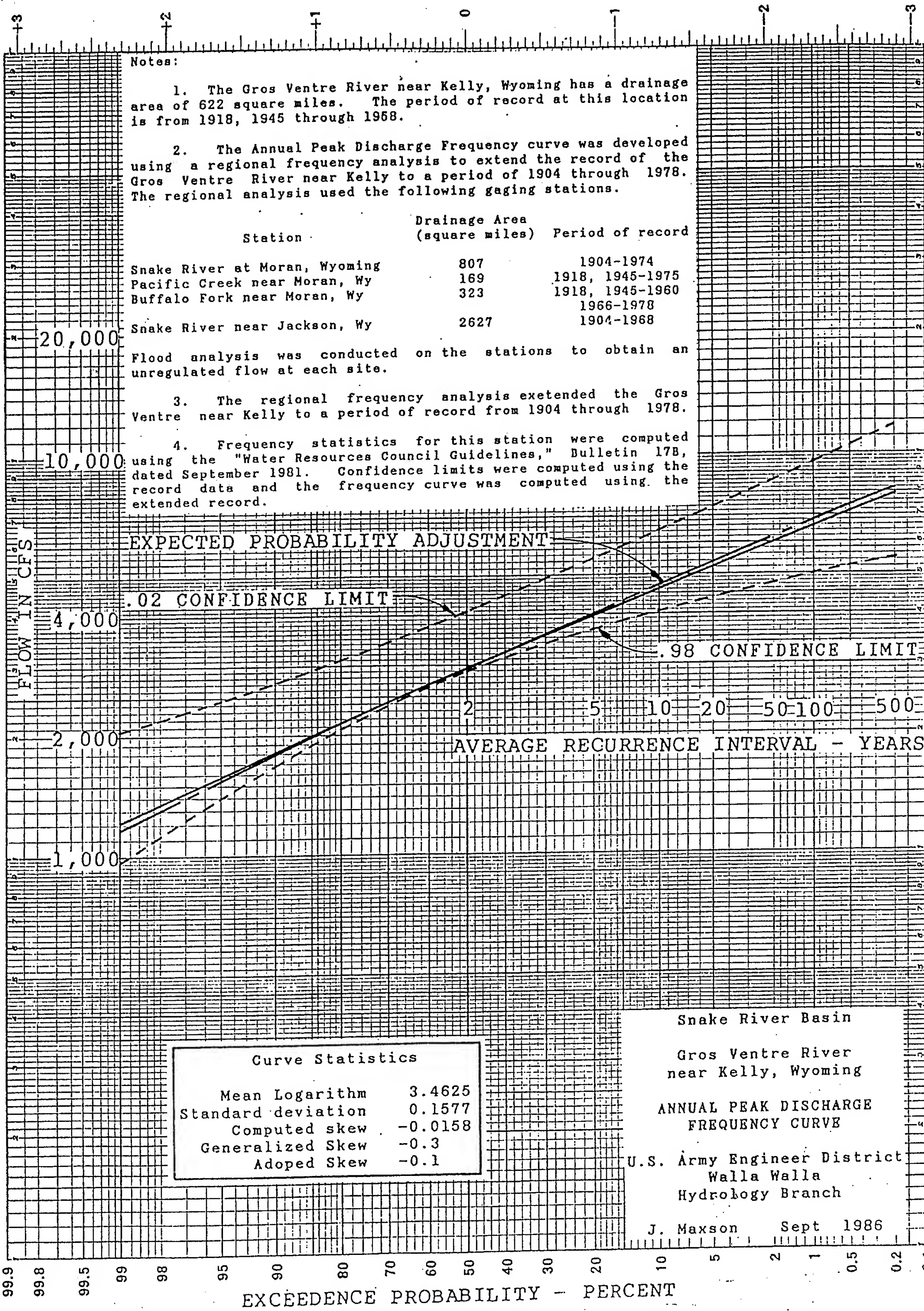
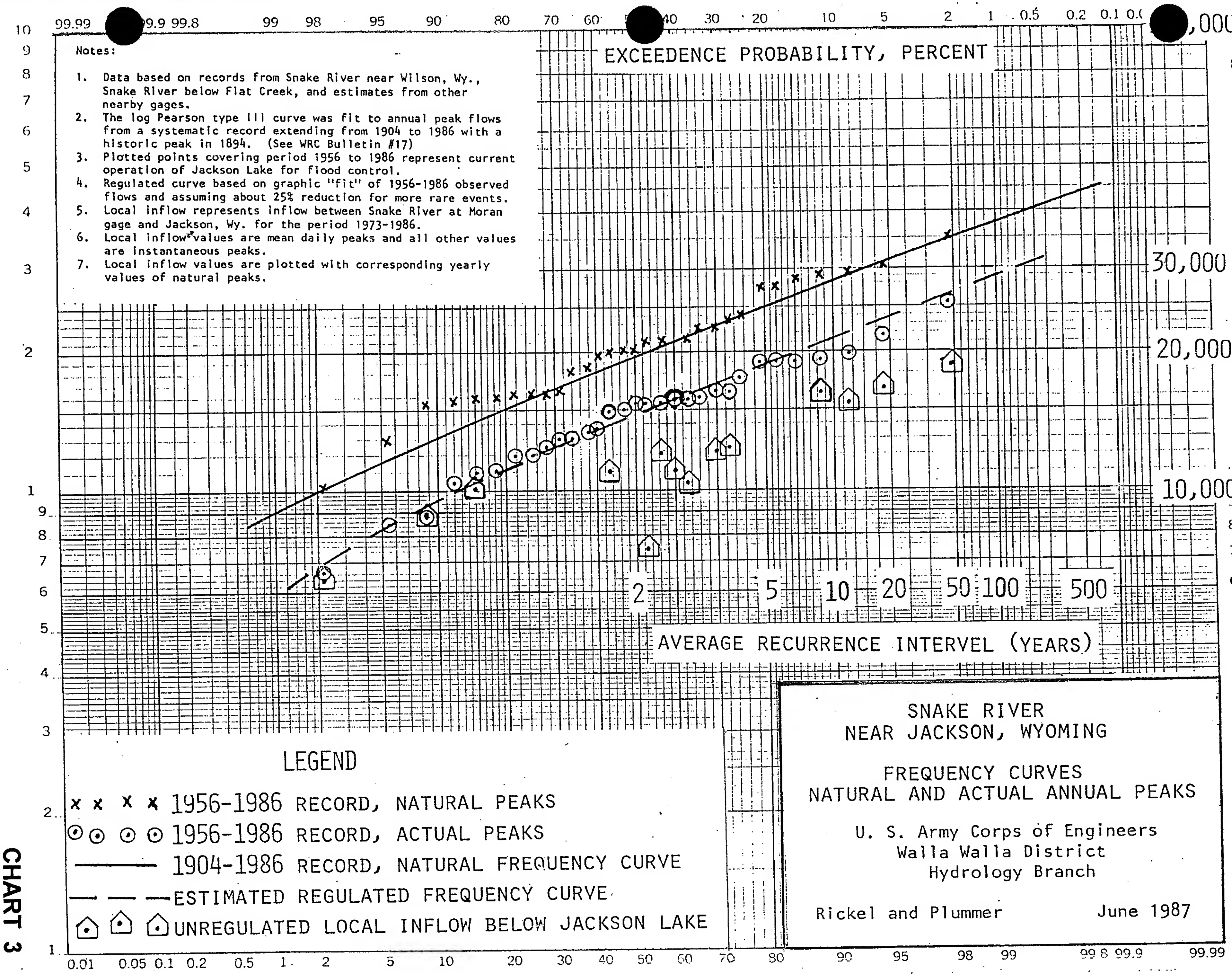


CHART 2



EXCEEDENCE PROBABILITY, PERCENT
Notes:
1. Data based on records from Snake River near Wilson, Wy., Snake River below Flat Creek, and estimates from other nearby gages.
2. The log Pearson type III curve was fit to annual peak flows from a systematic record extending from 1904 to 1986 with a historic peak in 1894. (See WRC Bulletin #17)
3. Plotted points covering period 1956 to 1986 represent current operation of Jackson Lake for flood control.
4. Regulated curve based on graphic "fit" of 1956-1986 observed flows and assuming about 25% reduction for more rare events.
5. Local inflow represents inflow between Snake River at Moran gage and Jackson, Wy. for the period 1973-1986.
6. Local inflow values are mean daily peaks and all other values are instantaneous peaks.
7. Local inflow values are plotted with corresponding yearly values of natural peaks.
30,000
20,000
10,000
2
5
10
20
50
100
500
AVERAGE RECURRENCE INTERVEL (YEARS)
LEGEND
1956-1986 RECORD, NATURAL PEAKS
1956-1986 RECORD, ACTUAL PEAKS
1904-1986 RECORD, NATURAL FREQUENCY CURVE
ESTIMATED REGULATED FREQUENCY CURVE
UNREGULATED LOCAL INFLOW BELOW JACKSON LAKE
SNAKE RIVER
NEAR JACKSON, WYOMING
FREQUENCY CURVES
NATURAL AND ACTUAL ANNUAL PEAKS
U. S. Army Corps of Engineers
Walla Walla District
Hydrology Branch
Rickel and Plummer
June 1987

CHART 3

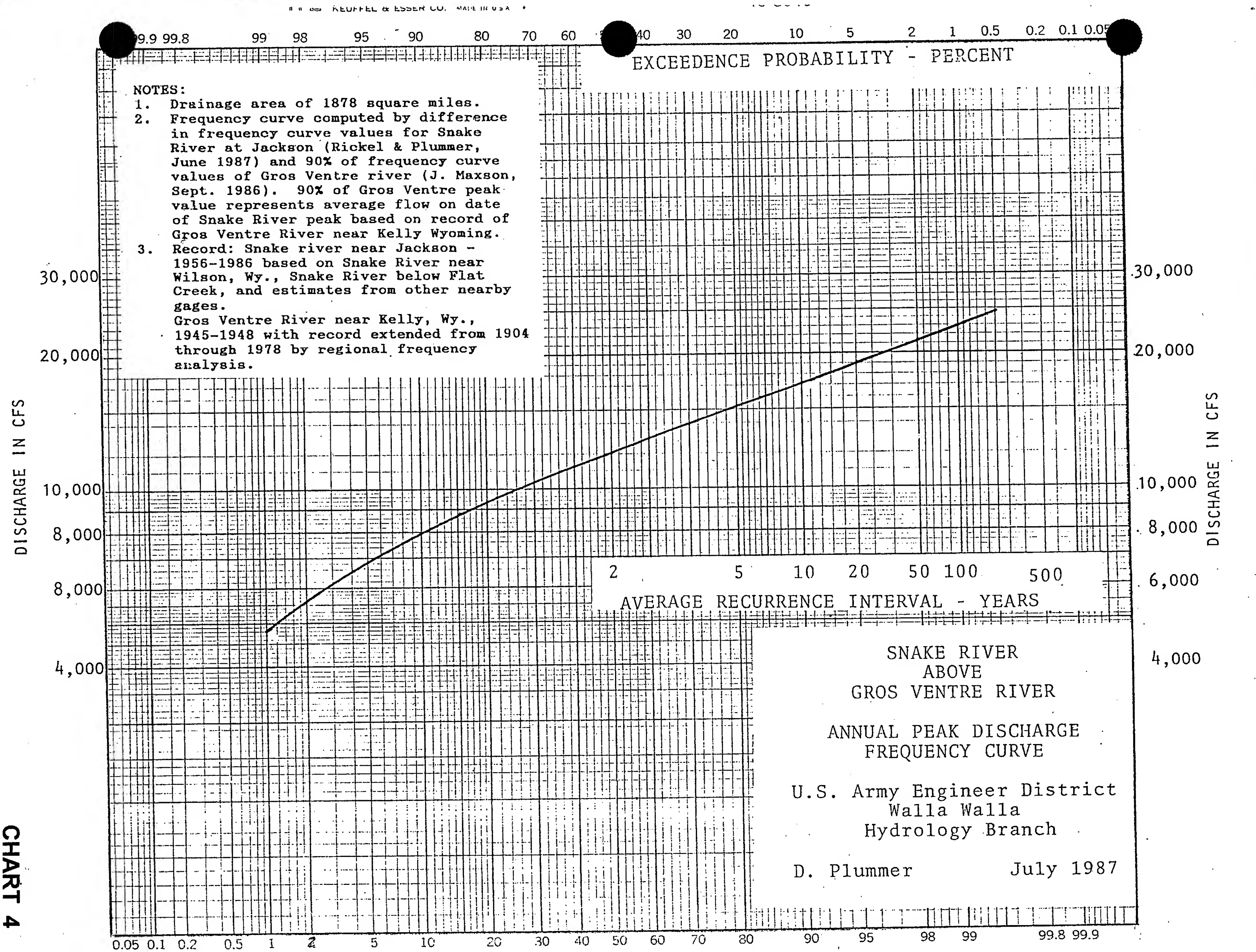
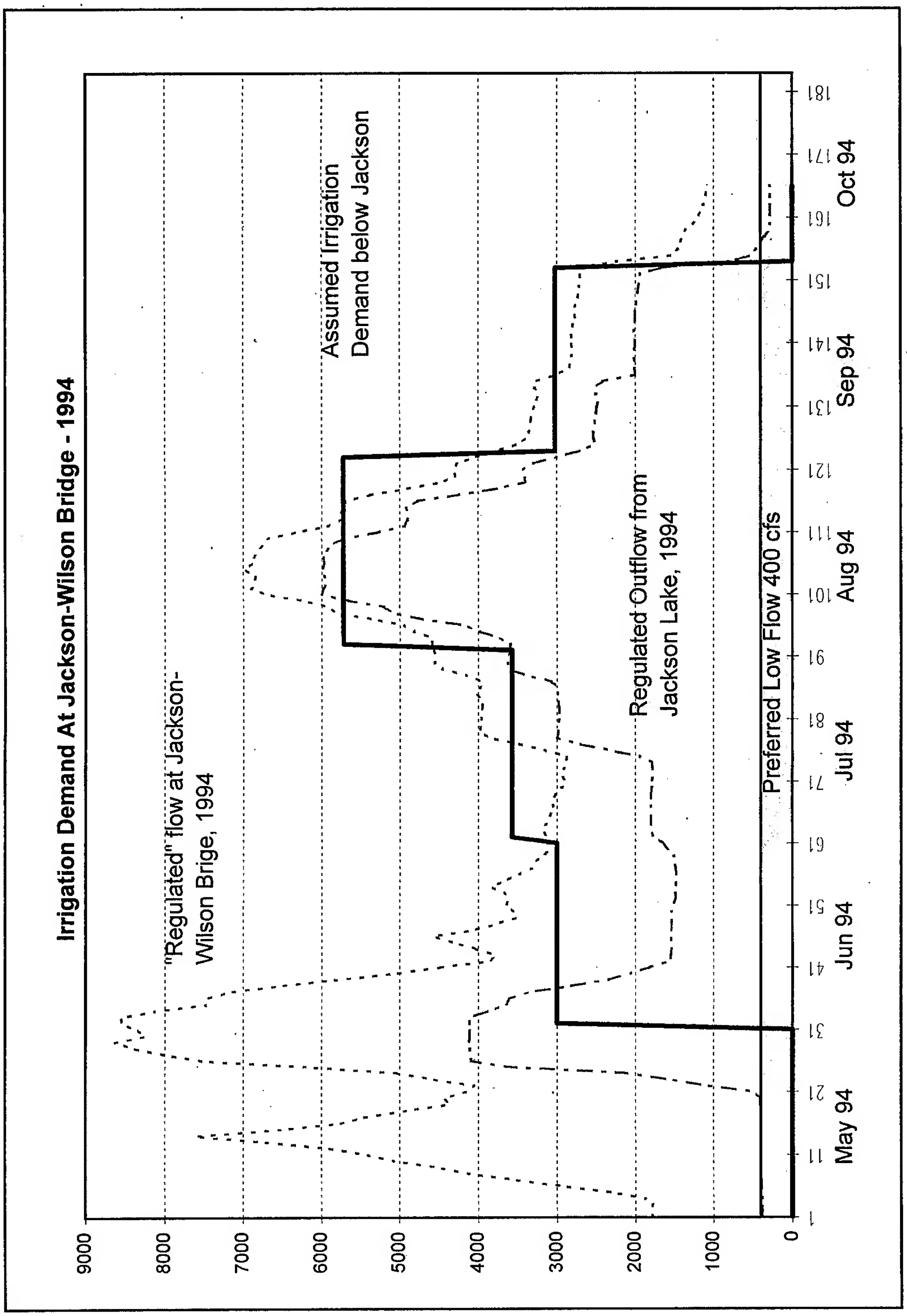

KEUFFEL & ESSER CO. MADE IN U.S.A.
EXCEEDENCE PROBABILITY - PERCENT
NOTES:
1. Drainage area of 1878 square miles.
2. Frequency curve computed by difference in frequency curve values for Snake River at Jackson (Rickel & Plummer, June 1987) and 90% of frequency curve values of Gros Ventre river (J. Maxson, Sept. 1986). 90% of Gros Ventre peak value represents average flow on date of Snake River peak based on record of Gros Ventre River near Kelly Wyoming.
3. Record: Snake river near Jackson - 1956-1986 based on Snake River near Wilson, Wy., Snake River below Flat Creek, and estimates from other nearby gages.
Gros Ventre River near Kelly, Wy., 1945-1948 with record extended from 1904 through 1978 by regional frequency analysis.
DISCHARGE IN CFS
30,000
20,000
10,000
8,000
6,000
4,000
AVERAGE RECURRENCE INTERVAL - YEARS
2
5
10
20
50
100
500
SNAKE RIVER
ABOVE
GROS VENTRE RIVER
ANNUAL PEAK DISCHARGE
FREQUENCY CURVE
U.S. Army Engineer District
Walla Walla
Hydrology Branch
D. Plummer
July 1987

CHART 4



Irrigation Demand At Jackson-Wilson Bridge - 1994
"Regulated" flow at Jackson-Wilson Brige, 1994
Assumed Irrigation Demand below Jackson
Regulated Outflow from Jackson Lake, 1994
Preferred Low Flow 400 cfs
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1
11
21
31
41
51
61
71
81
91
101
111
121
131
141
151
161
171
181
May 94
Jun 94
Jul 94
Aug 94
Sep 94
Oct 94

CHART 5

Jackson Lake Regulation

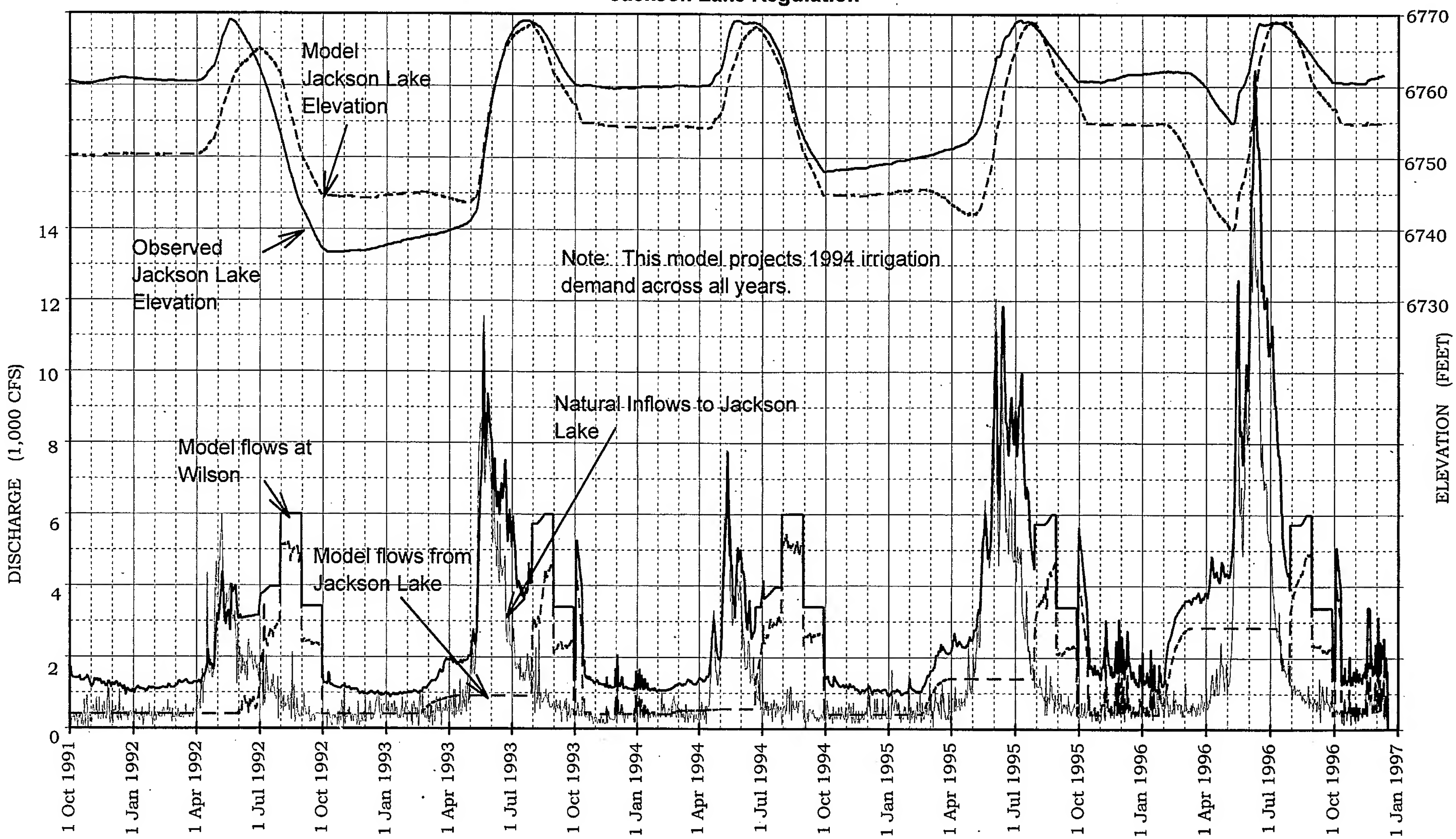


CHART 6

SNAKE RIVER AT JACKSON HOLE. ENVIRONMENTAL RESTORATION STUDY

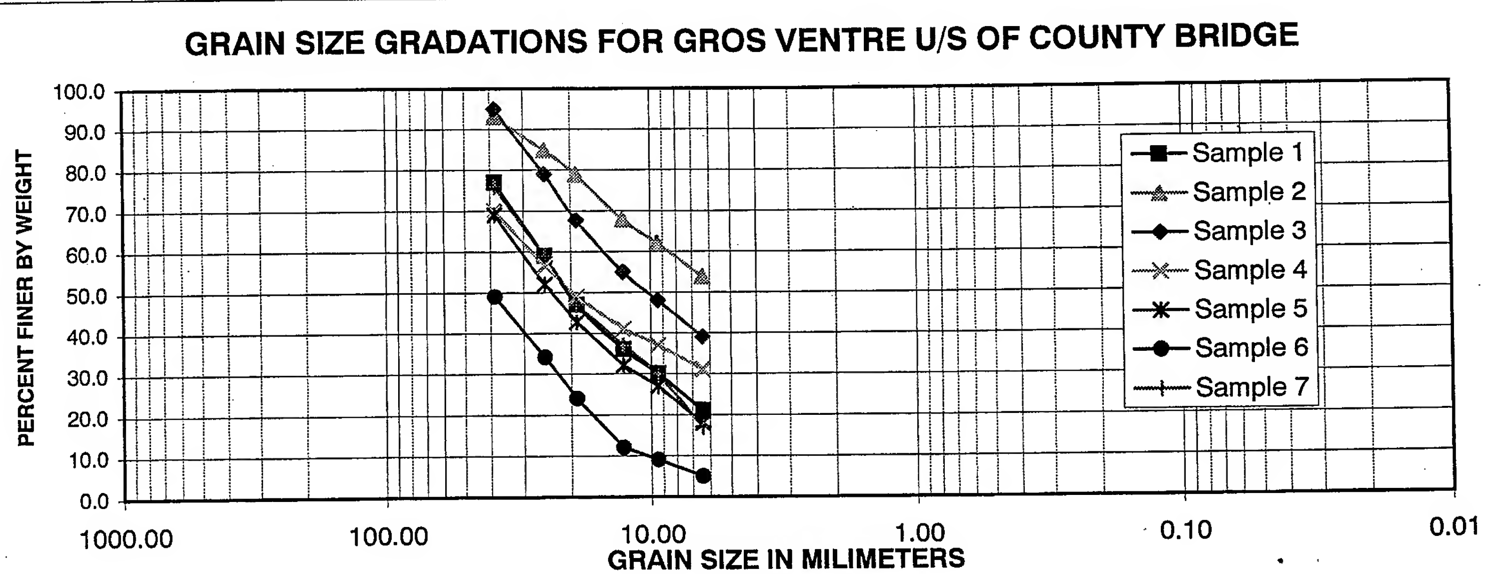
GRAIN-SIZE ANALYSIS FROM PREVIOUS STUDIES ON GROS VENTRE RIVER

UPSTREAM OF COUNTY HIGHWAY BRIDGE

Data from "EVALUATION OF SELECTED GRAVEL REMOVAL AT NINE RIVER LOCATIONS IN TETON COUNTY ...."

By M. M. Skinner, February, 1980.

SIZE MM	S1	S2	S3	S4	S5	S6	S7
38.5	77.0	93.0	95.0	70.0	69.0	49.0	76.0
25.0	59.0	84.8	79.0	56.5	52.0	34.0	59.0
19.0	47.0	78.8	67.7	49.0	42.7	24.0	47.0
12.7	36.0	67.8	55.0	41.0	32.0	12.0	37.0
9.4	30.0	62.0	48.0	37.0	27.0	9.0	30.0
6.4	21.0	53.8	39.0	31.0	18.0	5.0	17.0



SNAKE RIVER AT JACKSON HOLE. ENVIRONMENTAL RESTORATION STUDY

GRAIN-SIZE ANALYSIS FROM PREVIOUS STUDIES ON GROS VENTRE RIVER

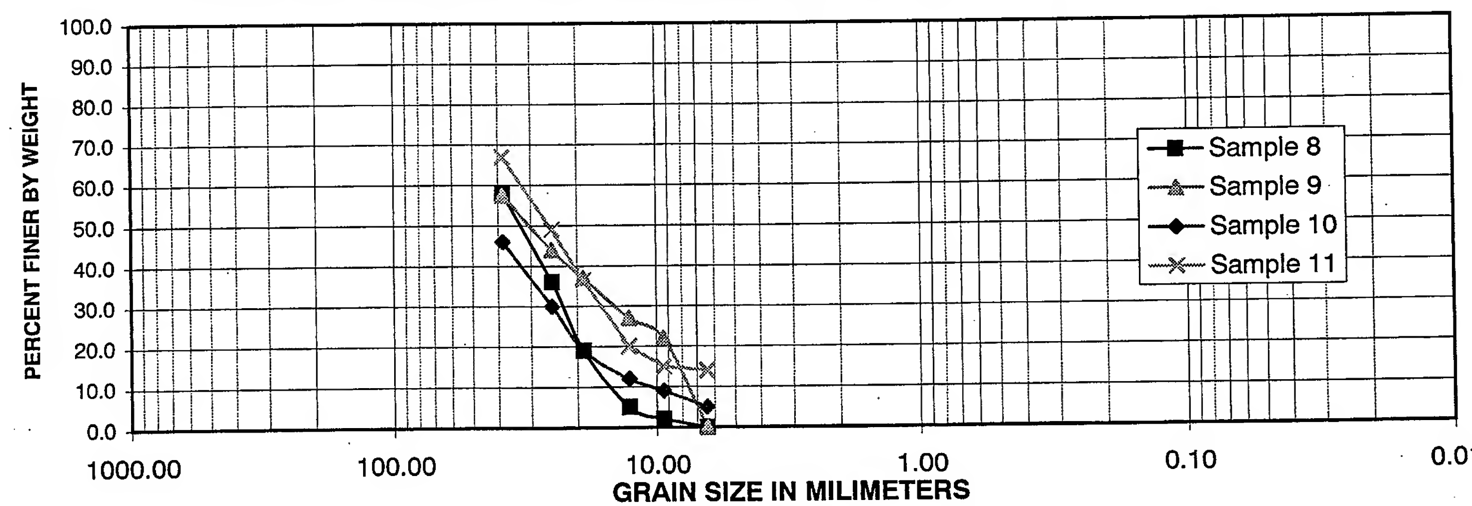
DOWNSTREAM OF COUNTY HIGHWAY BRIDGE

Data from "EVALUATION OF SELECTED GRAVEL REMOVAL AT NINE RIVER LOCATIONS IN TETON COUNTY ...."

By M. M. Skinner, February, 1980.

SIZE MM	S8	S9	S10	S11
38.5	58.0	57.5	46.0	67.0
25.0	36.0	44.0	30.0	49.0
19.0	19.0	37.0	19.0	36.5
12.7	5.0	27.0	12.0	20.0
9.4	2.0	22.0	9.0	15.0
6.4	0.0	0.0	5.0	14.0

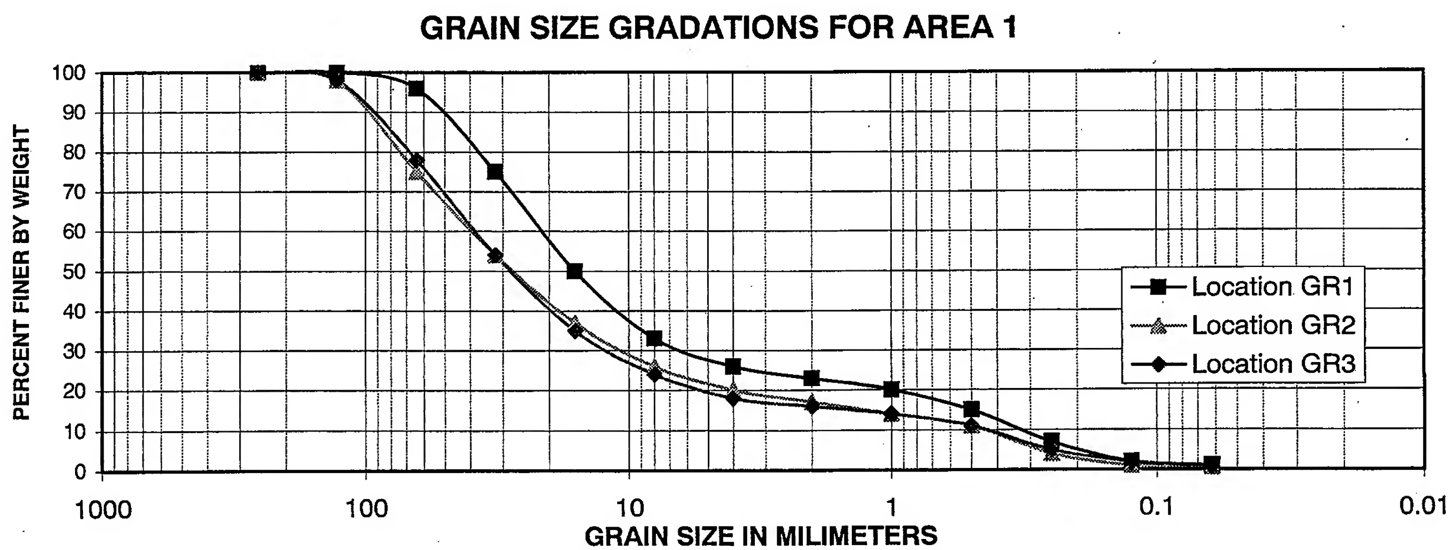
GRAIN SIZE GRADATIONS FOR GROS VENTRE D/S OF COUNTY BRIDGE



RESULTS OF GRAIN SIZE ANALYSIS FOR SAMPLES AT AREA 1

SNAKE RIVER AT JACKSON HOLE. ENVIRONMENTAL RESTORATION STUDY . SAMPLED AUG-NOV 1997

SIEVE	SIZE MM	S1-GR1	S1-GR2	S1-GR3	AVG
10"	256	100	100	100	100.00
5"	128	100	98	98	98.67
2.5"	64	96	75	78	83.00
1.25"	32	75	54	54	61.00
5/8"	16	50	37	35	40.67
5/16"	8	33	26	24	27.67
#5	4	26	20	18	21.33
#10	2	23	17	16	18.67
#18	1	20	14	14	16.00
#35	0.5	15	11	11	12.33
#60	0.25	7	4	5	5.33
#120	0.125	2	1	2	1.67
#230	0.062	1	0.6	0.8	0.80



RESULTS OF GRAIN SIZE ANALYSIS FOR SAMPLES AT AREA 4

SNAKE RIVER AT JACKSON HOLE. ENVIRONMENTAL RESTORATION STUDY . SAMPLED AUG-NOV 1996

SIEVE	SIZE MM	S4-GR1	S4-GR2	S4-GR3	AVG
10"	256	100	100	100	100.00
5"	128	100	95	98	97.67
2.5"	64	90	74	83	82.33
1.25"	32	64	52	64	60.00
5/8"	16	40	34	43	39.00
5/16"	8	27	23	28	26.00
#5	4	23	17	19	19.67
#10	2	20	13	14	15.67
#18	1	18	11	10	13.00
#35	0.5	12	8	6	8.67
#60	0.25	4	4	3	3.67
#120	0.125	1	1	1	1.00
#230	0.062	0.5	0.6	0.4	0.50

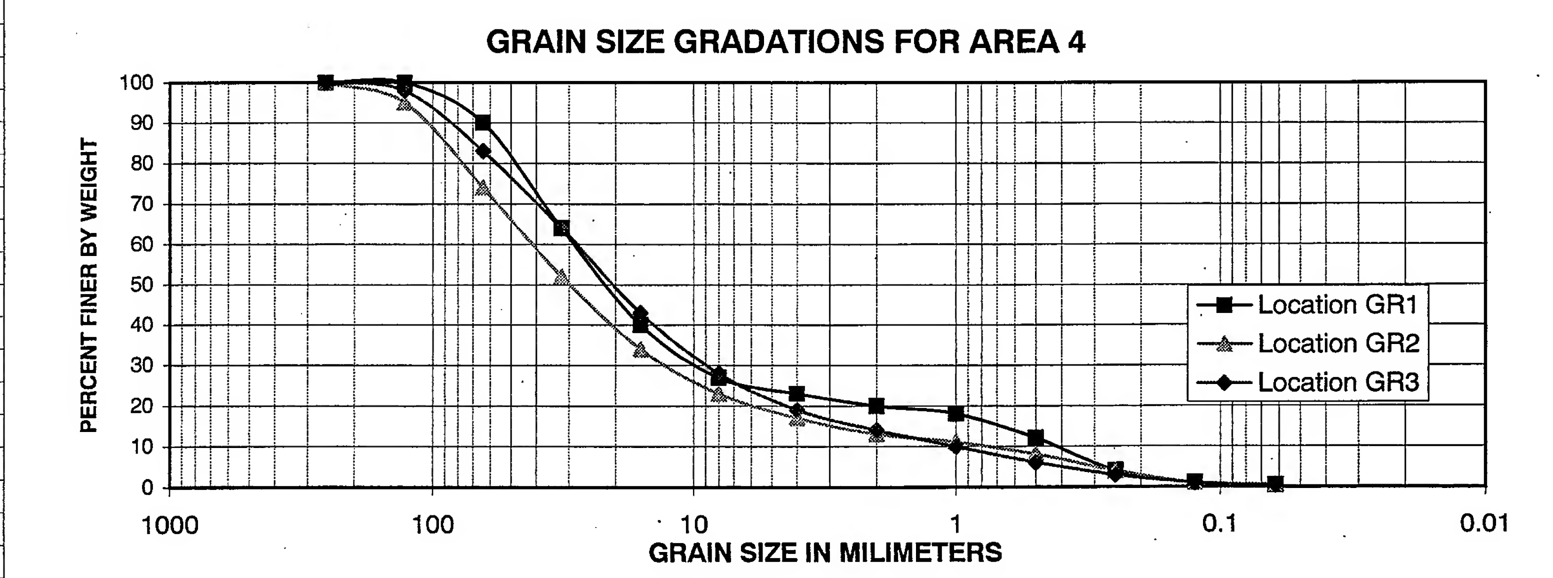


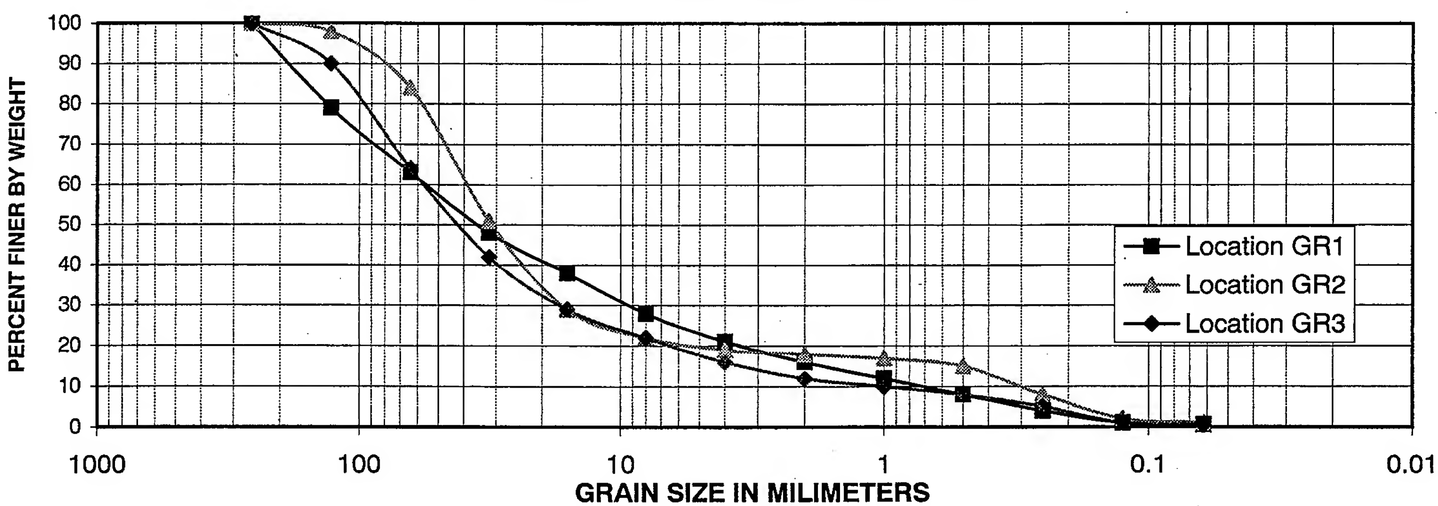
CHART 10

RESULTS OF GRAIN SIZE ANALYSIS FOR SAMPLES AT AREA 9

SNAKE RIVER AT JACKSON HOLE. ENVIRONMENTAL RESTORATION STUDY . SAMPLED AUG-NOV 1997

SIEVE	SIZE MM	S9-GR1	S9-GR2	S9-GR3	AVG
10"	256	100	100	100	100
5"	128	79	98	90	89.00
2.5"	64	63	84	64	70.33
1.25"	32	48	51	42	47.00
5/8"	16	38	29	29	32.00
5/16"	8	28	22	22	24.00
#5	4	21	19	16	18.67
#10	2	16	18	12	15.33
#18	1	12	17	10	13.00
#35	0.5	8	15	8	10.33
#60	0.25	4	8	5	5.67
#120	0.125	1	2	1	1.33
#230	0.062	0.6	1.1	0.6	0.77

GRAIN SIZE GRADATIONS FOR AREA 9



SNAKE RIVER AT JACKSON HOLE. ENVIRONMENTAL RESTORATION STUDY .

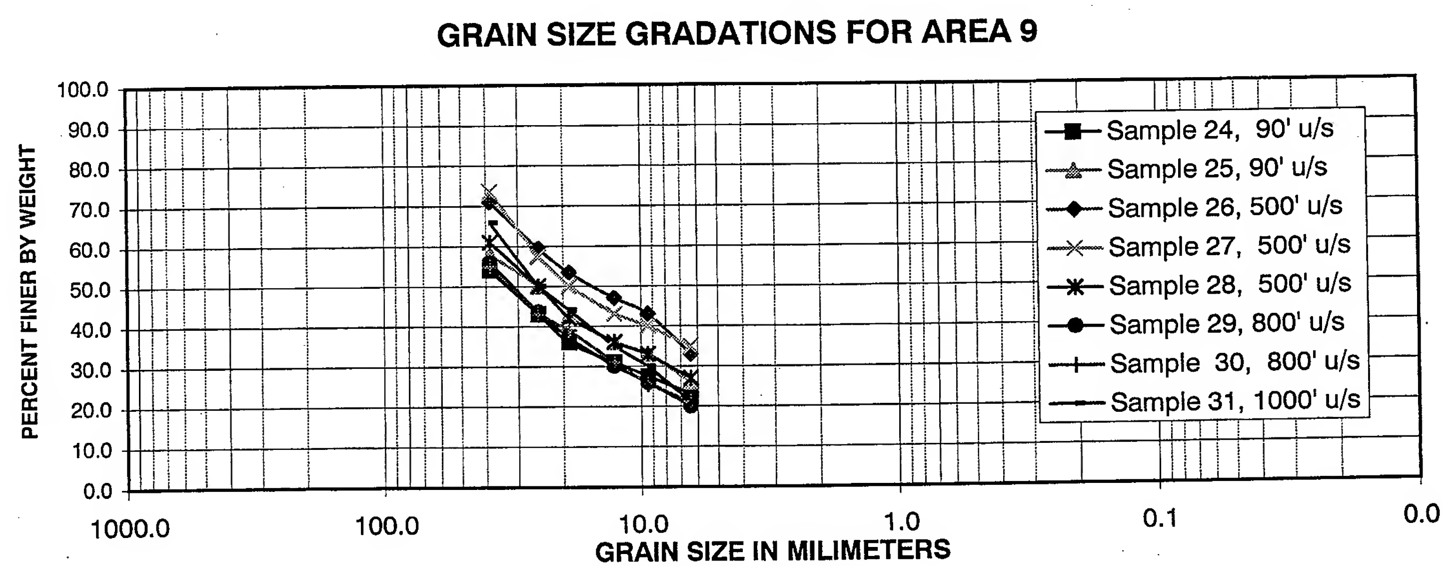
GRAIN SIZE ANALYSIS FOR SAMPLES AT AREA 9

UPSTREAM OF JACKSON - WILSON BRIDGE

Data from "EVALUATION OF SELECTED GRAVEL REMOVAL AT NINE RIVER LOCATIONS IN TETON COUNTY ...."

By M. M. Skinner, February, 1980.

SIZE MM	S24	S25	S26	S27	S28	S29	S30	S31
38.5	54.0	58.0	71.0	73.6	61.0	56.0	54.9	65.9
25.0	43.0	50.0	59.5	57.5	50.0	43.5	43.0	50.0
19.0	36.0	42.5	53.5	50.0	42.0	37.0	39.0	44.0
12.7	31.0	36.0	47.0	43.0	36.0	30.0	31.0	35.0
9.4	27.5	33.0	43.0	40.0	33.0	26.0	25.5	30.0
6.4	23.0	26.0	33.0	35.0	27.0	20.0	21.0	21.0



RESULTS OF GRAIN SIZE ANALYSIS FOR SAMPLES AT AREA 10

SNAKE RIVER AT JACKSON HOLE. ENVIRONMENTAL RESTORATION STUDY . SAMPLED AUG-NOV 1997

SIEVE	SIZE MM	S10-GR1	S10-GR2	S10-GR3	AVG
10"	256	100	100	100	100
5"	128	97	88	92	92.33
2.5"	64	78	70	60	69.33
1.25"	32	51	52	39	47.33
5/8"	16	31	37	25	31.00
5/16"	8	21	27	18	22.00
#5	4	17	20	13	16.67
#10	2	16	17	11	14.67
#18	1	15	14	10	13.00
#35	0.5	13	8	9	10.00
#60	0.25	7	3	6	5.33
#120	0.125	3	0.8	2	1.93
#230	0.062	1.8	0.3	0.8	0.97

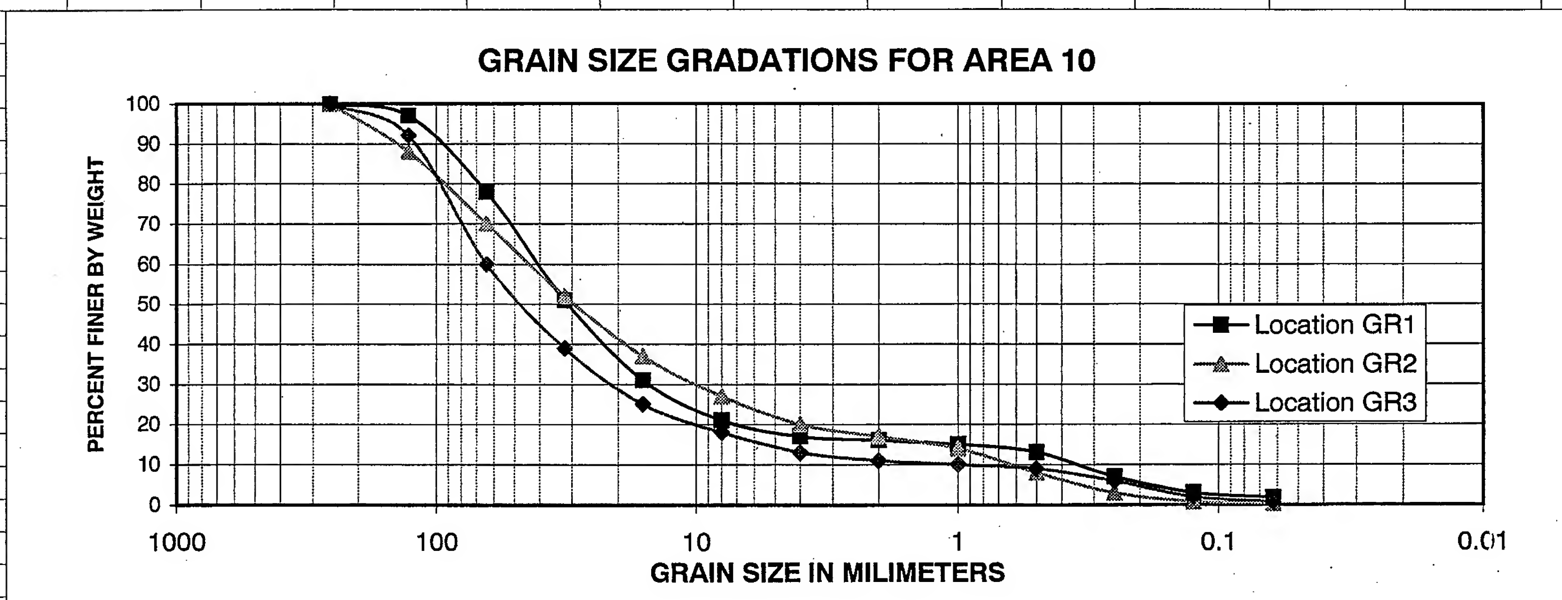


CHART 13

AVERAGE GRAIN SIZES FOR EACH OF THE FOUR RESTORATION AREAS

SNAKE RIVER AT JACKSON HOLE. ENVIRONMENTAL RESTORATION STUDY . SAMPLED AUG-NOV 1997

		% PASSING				% RETAINED			
SIEVE	SIZE MM	S1	S4	S9	S10	S1	S4	S9	S10
10"	256	100	100	100	100	0	0	0	0
5"	128	98.67	97.67	89	92.33	1.33	2.33	11	7.67
2.5"	64	83	82.33	70.33	69.33	15.67	15.34	18.67	23
1.25"	32	61	60	47	47.33	22	22.33	23.33	22
5/8"	16	40.67	39	32	31.00	20.33	21	15	16.33
5/16"	8	27.67	26	24	22.00	13	13	8	9
#5	4	21.33	19.67	18.67	16.67	6.34	6.33	5.33	5.33
#10	2	18.67	15.67	15.33	14.67	2.66	4	3.34	2
#18	1	16	13	13	13.00	2.67	2.67	2.33	1.67
#35	0.5	12.33	8.67	10.33	10.00	3.67	4.33	2.67	3
#60	0.25	5.33	3.67	5.67	5.33	7	5	4.66	4.67
#120	0.125	1.67	1	1.33	1.93	3.66	2.67	4.34	3.4
#230	0.062	0.8	0.5	0.77	0.97	0.87	0.5	0.56	0.96
	0.032					0.8	0.5	0.77	0.97

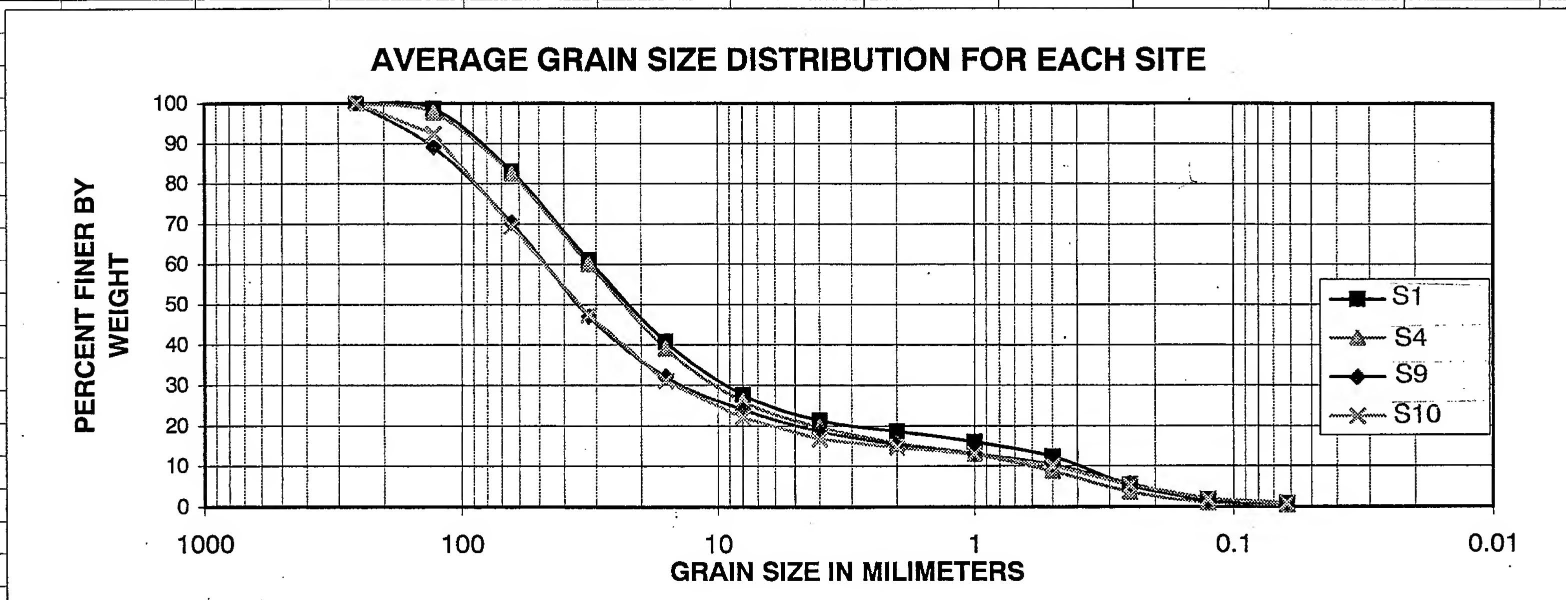


CHART 14

AVERAGE GRAIN SIZES FOR EACH OF THE FOUR RESTORATION AREAS

SNAKE RIVER AT JACKSON HOLE. ENVIRONMENTAL RESTORATION STUDY . SAMPLED AUG-NOV 1997

SIEVE	SIZE MM	% PASSING S1	% PASSING S4	% PASSING S9	% PASSING S10	% RETAINED S1	% RETAINED S4	% RETAINED S9	% RETAINED S10
10"	256	100	100	100	100	0	0	0	0
5"	128	98.67	97.67	89	92.33	1.33	2.33	11	7.67
2.5"	64	83	82.33	70.33	69.33	15.67	15.34	18.67	23
1.25"	32	61	60	47	47.33	22	22.33	23.33	22
5/8"	16	40.67	39	32	31.00	20.33	21	15	16.33
5/16"	8	27.67	26	24	22.00	13	13	8	9
#5	4	21.33	19.67	18.67	16.67	6.34	6.33	5.33	5.33
#10	2	18.67	15.67	15.33	14.67	2.66	4	3.34	2
#18	1	16	13	13	13.00	2.67	2.67	2.33	1.67
#35	0.5	12.33	8.67	10.33	10.00	3.67	4.33	2.67	3
#60	0.25	5.33	3.67	5.67	5.33	7	5	4.66	4.67
#120	0.125	1.67	1	1.33	1.93	3.66	2.67	4.34	3.4
#230	0.062	0.8	0.5	0.77	0.97	0.87	0.5	0.56	0.96
	0.032					0.8	0.5	0.77	0.97

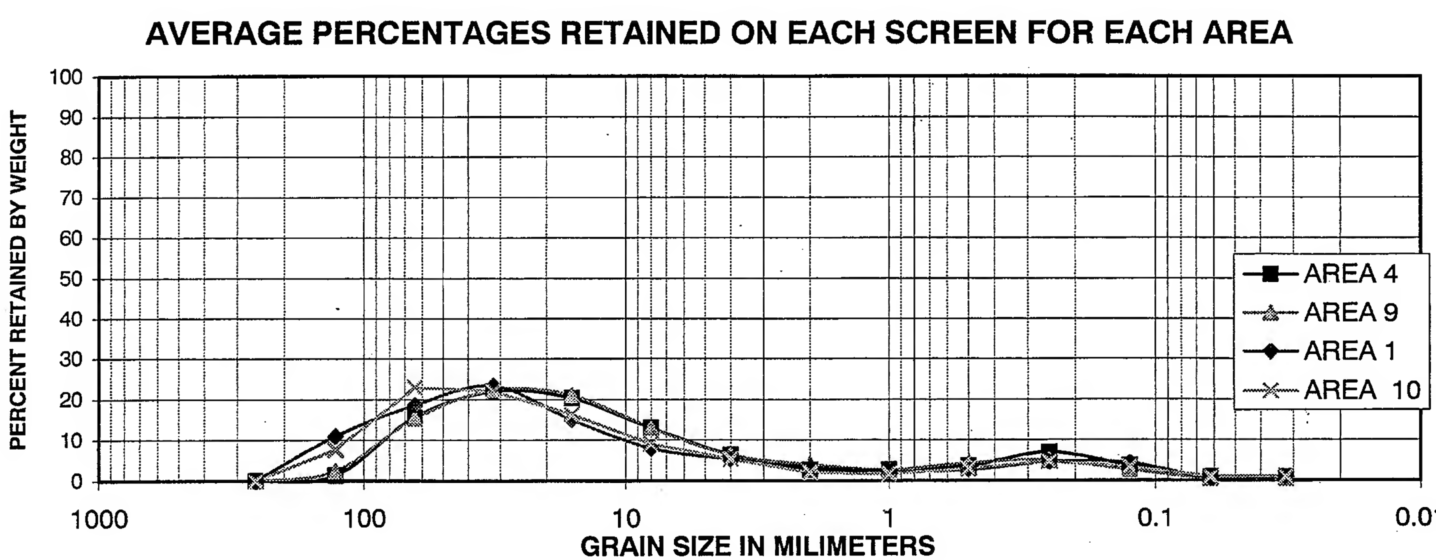


CHART 15

TABLE 1

REPRESENTATIVE CLIMATOLOGICAL DATA PERTINENT TO JACKSON HOLE STUDIES 1/

Climatological Station	Station Elevation (feet msl)	Length of Record 2/ Temp. (years)	Length of Record 2/ Precip. (years)	Temperature 3/ Annual Mean (°F)	Temperature 3/ Recorded Maximum (°F)	Temperature 3/ Recorded Minimum (°F)	Temperature 3/ January Average (°F)	Temperature 3/ July Average (°F)	Annual Precipitation 3/ Annual Average (inches)	Annual Precipitation 3/ Maximum Year	Annual Precipitation 3/ Maximum Amount (inches)	Annual Precipitation 3/ Minimum Year	Annual Precipitation 3/ Minimum Amount (inches)	Snowfall 3/ Annual Average (inches)
Palisades Dam, ID	5,385	40	41	43.6	97	-32	20.8	67.7	19.58	1982	28.25	1966	13.47	81.8
Jackson, WY	6,230	57	64	38.0	94 4/	-50 4/	16.0	60.8	15.27	1983	24.07	1979	8.84	87.8
Alta 1 NNW, WY	6,430	76	78	39.7	95	-35	18.4	63.2	21.29	1983	33.62	1926	9.47	112.8
Moose, WY	6,470	30	30	36.9	93	-46	13.4	61.0	21.25	1971	26.85	1976	16.45	190.7
Moran 5 WNW, WY	6,789	75	76	35.6	90 5/	-50 5/	13.0	59.2	23.25	1975	31.14	1952	13.51	199.7
Snake River, WY	6,882	71	71	34.2	97	-46	12.8	58.2	32.64	1913	50.10	1907	21.32	244.1
Lake Yellowstone, WY	7,770	59	70	32.1	91	-50	10.3	55.3	19.42	1970	26.16	1976	12.62	157.1

1/ Data was obtained from the following in order of preference: National Weather Service (NWS) State Office in Cheyenne, Wyoming; NWS State Office in Boise, Idaho; "Wyoming Climate Atlas" (1987), published by the University of Nebraska Press; "Climatological Handbook" (1969), edited and published through the Meteorologic Committee, Pacific Northwest River Basin Commission; and National Climatic Center monthly records.

2/ Length of record for temperature and precipitation data is for the period through calendar year (CY) 1987. At some stations the record is intermittent. In most cases, the length of record for snowfall is significantly less than for temperature and precipitation.

3/ All temperature data, the annual average precipitation data, and the annual average snowfall data is derived from the subset of available information for a given station in the NWS base period 1951 through 1980. Maximum and minimum yearly precipitation totals are for the entire period of record through CY 1987.

4/ Extreme temperatures for the period of record at Jackson are 101 degrees F. and -52 degrees F.

5/ Extreme temperatures for the period of record at Moran are 92 degrees F. and -63 degrees F.

TABLE 2

REPRESENTATIVE SNOW COURSES PERTINENT TO JACKSON HOLE STUDIES 1/

Snow Course Station	Drainage Basin	Elevation (feet msl)	Length of Record (years)	Average Recorded Snow Water Equivalents 2/						Maximum Recorded Snow Depth and Snow Water Equivalents 3/			
				1 January (inches)	1 February (inches)	1 March (inches)	1 April (inches)	1 May (inches)	1 June (inches)	Snow Depth (inches)	(year)	Water Content (inches)	(year)
Moran	Snake River	6,750	70	5.5	9.4	11.8	12.9	N/A 4/	N/A	62	1943	20.1	1943
Snake River Station	Snake River	6,920	70	8.6	14.4	18.5	21.5	N/A	N/A	97	1943	32.6	1943
Coulter Creek	Snake River	7,020	70	9.7	15.1	19.9	22.7	17.8	0.0	110	1943	37.8	1943
Base Camp	Snake River	7,030	59	8.7	14.2	17.8	20.7	14.5	0.0	90	1943	29.9	1972
Glade Creek	Snake River	7,040	70	9.8	15.9	20.3	23.7	21.7	N/A	104	1943	36.6	1943
Grassy Lake	Snake River	7,265	48	15.1	24.0	30.3	36.2	34.9	15.4	126	1976	51.0	1971
Snow King Mountain	Snake River	7,660	30	6.6	10.3	12.9	15.5	13.6	N/A	65	1971	22.3	1971
Salt River Summit	Snake River	7,700	41	6.5	11.0	14.1	16.5	13.9	0.0	72	1971	26.3	1971
Teton Pass W.S.	Snake River	7,740	16	N/A	17.5	22.4	26.8	28.3	N/A	107	1974	39.4	1986
Lewis Lake Divide	Snake River	7,850	70	17.8	28.0	35.8	42.7	43.5	28.8	167	1943	76.0	1927
Four Mile Meadows	Snake River	7,860	53	N/A	9.0	11.2	13.4	N/A	N/A	62	1943	21.1	1943
East Rim Divide	Upper Green R.	7,930	53	5.6	8.9	11.3	13.3	11.1	0.0	69	1936	24.5	1936
Gros Ventre Summit	Snake River	8,750	41	5.8	8.3	9.9	12.1	11.5	0.0	75	1986	21.2	1986
Togwotee Pass	Snake River	9,580	53	12.8	19.8	24.7	30.0	33.0	25.8	118	1971	48.9	1971

1/ Data sources include the "Wyoming Annual Data Summaries," compiled and released annually by the Soil Conservation Service.
2/ Snow course data is current through WY 87. Average recorded snow water equivalents are for the base period 1961 to 1985.
3/ Maximum snow depths and maximum snow water content do not necessarily occur at the same time. Generally, snow depth begins to decrease before snow water equivalents.
4/ N/A = Not Available. The snow course may not be normally measured at this time, or remaining snowpack is normally negligible.

TABLE 3

NATURAL AND REGULATED FLOOD DISCHARGES AT KEY GAGING LOCATIONS

Exceedence Probability (percent)	Average Recurrence Interval (years)	Snake Above Gros Ventre [1/] Natural (cfs)	Snake Above Gros Ventre [1/] Regulated (cfs)	Gros Ventre Near Kelly [2/] Natural (cfs)	Snake Near Jackson [3/] Natural (cfs)	Snake Near Jackson [3/] Regulated (cfs)
50	2	15,700	12,000	2,900	19,700	14,600
20	5	20,200	15,300	3,900	25,200	18,800
10	10	22,900	17,200	4,600	28,600	21,300
4	25	26,200	19,500	5,400	32,600	24,400
2	50	28,400	21,200	6,000	35,500	26,700
1	100	30,500	22,900	6,600	38,200	28,600
0.2	500	36,600	36,600	7,900	44,300	44,300

1/ Natural peak flow data for the Snake River above the Gros Ventre River confluence is derived from CENPW frequency curves dated February 1975. Regulated peak flow data is derived from a CENPW frequency curve dated July 1987.

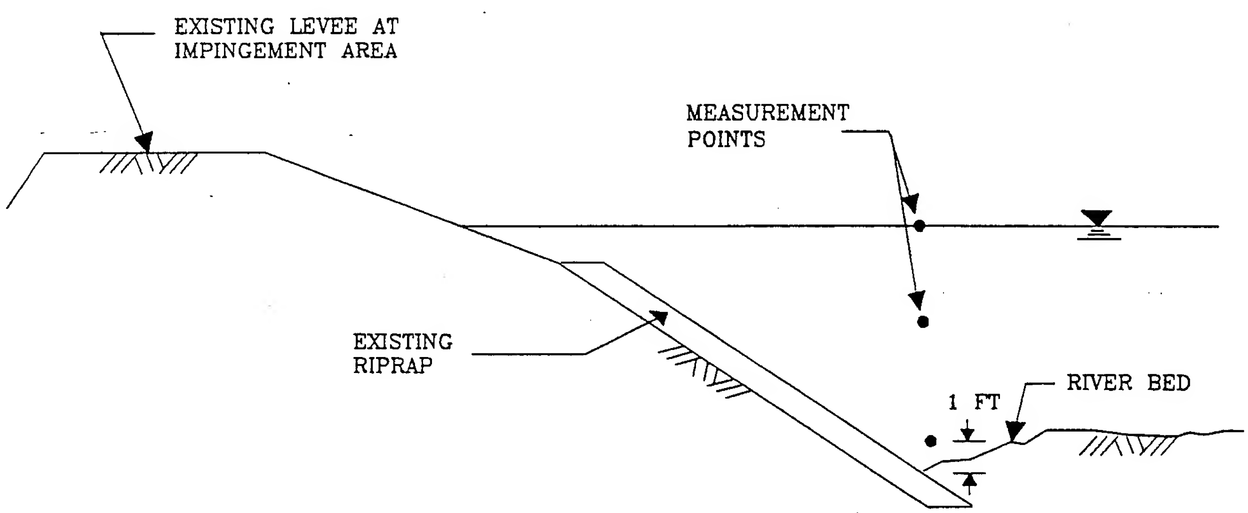
2/ Natural peak flow data for the Gros Ventre River near Kelly is derived from CENPW frequency curves dated September 1986.

3/ Natural and regulated peak flow data for the Snake River below the Gros Ventre River confluence is derived from CENPW frequency curves dated June 1987.

TABLE 4

Point Velocity Measurements At Impingement Locations

Location of Impingement Area	Measurement Depth (ft)	Point Velocity (fps)
Right Bank:	Surface	10.93
600 Ft. Upstream	3	11.11
from Section 0.2	(1 ft. above toe) 6	10.41
Left Bank:	Surface	10.17
700 Ft. Upstream	3	10.41
from Section 0.1	(1 ft. above toe) 6	9.94
Left Bank:	Surface	10.41
260 Ft. Upstream	3	10.93
from Section 1	(1 ft. above toe) 6	10.41
Right Bank:	Surface	10.41
200 Ft. Upstream	3	10.17
from Section 6	(1 ft. above toe) 6	8.93



NOTES:

1. Distances are measured along the levee centerline from the point of intersection with the referenced cross section.

2. Velocity measurements were taken in June 1974 at various locations along the Federal project levees during a Snake R. discharge of 13,790 cfs.

TABLE 4 (Continued)

Location of Impingement Area	Measurement Depth (ft)	Point Velocity (fps)
Right Bank:	Surface	11.31
560 Ft. Downstream	3	9.31
from Section 9	(1 ft. above toe) 6	7.82
Right Bank:	Surface	7.82
300 Ft. Downstream	3	7.46
from Section 3		
Left Bank:	Surface	10.17
340 Ft. Upstream	3	8.75
from Section 10	(1 ft. above toe) 6	3.82
Right Bank:	Surface	7.63
500 Ft. Upstream	3	6.99
from Section 12	(1 ft. above toe) 6	3.30
Left Bank:	Surface	8.01
400 Ft. Upstream	3	6.84
from Section 13	(1 ft. above toe) 6	3.82
Right Bank:	Surface	7.14
460 Ft. Downstream	3	5.22
from Section 15		
Right Bank:	Surface	10.41
420 Ft. Upstream	3	10.17
from Section 16	6	9.31
	(1 ft. above toe) 9	6.32
Right Bank:	Surface	8.25
600 Ft. Upstream	3	7.63
from Section 17	(1 ft. above toe) 6	5.87
Right Bank:	Surface	10.66
300 Ft. Downstream	3	9.11
from Section 19	(1 ft. above toe) 6	7.14
Right Bank:	Surface	10.93
260 Ft. Upstream	3	9.82
from Section 21		
Right Bank:	Surface	11.50
700 Ft. Downstream	3	10.66
from Section 29	(1 ft. above toe) 6	8.41
Right Bank:	Surface	9.31
540 Ft. Upstream	3	9.11
from Section 33	(1 ft. above toe) 6	7.46

TABLE 4 (Continued)

Location of Impingement Area	Measurement Depth (ft)	Point Velocity (fps)
Left Bank:	Surface	8.75
960 Ft. Upstream	3	8.93
from Section 35	(1 ft. above toe) 6	7.82
Right Bank:	Surface	8.75
220 Ft. Upstream	3	9.31
from Section 35	6	6.57
	(1 ft. above toe) 9	5.48
Left Bank:	Surface	7.14
700 Ft. Downstream	3	7.30
from Section 38	(1 ft. above toe) 6	6.32
Left Bank:	Surface	10.66
40 Ft. Downstream	3	10.66
from Section 40	(1 ft. above toe) 6	9.51
Right Bank:	Surface	10.41
400 Ft. Upstream	3	8.21
from Section 42		
Right Bank:	Surface	9.51
840 Ft. Downstream	3	6.31
from Section 42 (At end of groin)		
Left Bank:	Surface	10.93
440 Ft. Downstream	3	9.51
from Section 44	(1 ft. above toe) 6	7.82
Right Bank:	Surface	6.44
560 Ft. Downstream		
from Section 46		

TABLE 5

1997 HIGH-WATER MARKS

	AREA 1		AREA 4		AREA 9		AREA 10	
	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT
R1	-----	5998.89	6066.56	6069.91	6160.03	6159.47	6227.49	6225.45
R2	-----	6003.09	6070.86	6071.65	6162.80	6162.53	6231.18	6233.29
R3	-----	6004.78	6076.20	6076.27	6162.93	6164.49	6236.66	6242.11
R4	-----	6006.86	6082.21	-------	6167.25	6166.56	6243.77	6241.63
R5	-----	6009.75	6085.66	6085.48	6173.63	6172.25	6254.11	6248.27

*Note: The marks were set under the direction of Rick Gay of the Teton County Natural Resource District (TCNRD) on 12-13 June 1997. Several markers were later washed away and had to be re-established based on debris lines. On 11 June 1997 a peak flow of 32027 cfs was measured at the USGS Gage, Snake River Below Flat Creek. Elevation datum is 1929 NGVD.

TABLE 6

COMPARISON OF 100-YEAR FLOOD WATER-SURFACE ELEVATIONS FOR AREA 1

RANGE LABEL	FIS LABEL	FIS DIST	1996 DIST	FIS REG.*	FIS RERUN*	1996 EXISTING	1996 IMPROVED
104.00	C	0	0	5976.7	5976.7	5976.7	5976.7
105.00	D	3800	3800	5986.1	5986.3	5986.7	5986.7
R1	E	8000	8750	5998.0	5998.0	5998.8	5998.7
R2			9830			6001.0	6000.7
R3			10710			6003.9	6003.8
R4			11730			6006.7	6006.5
R5		12000	12690		6007.6	6010.6	6009.5
108.00	F	15900	17125	6022.9	6022.6	6022.1	6021.4
109.00	G	20400	21935	6036.2	6035.6	6037.3	6037.7
110.00	H	24900	26345	6052.4	6052.3	6050.8	6050.6

*Regulatory water-surface elevations from 1989 FIS study.
*The May 4, 1989 FIS study used a 1976 version HEC-2 updated in 1982 to run a model based on 1973 surveys. This column inticates results using same data and a 1990 version of HEC-2.
All elevations are in feet NGVD 1929. Discharge: 23,300 cfs.

TABLE 7

COMPARISON OF 100-YEAR FLOOD WATER-SURFACE ELEVATIONS FOR AREA 4

RANGE LABEL	FIS LABEL	FIS DIST	1996 DIST	FIS REG.	FIS RERUN*	1996 EXISTING	1996 IMPROVED
109.00	G	0	0	6036.2	6035.6	6036.2	6036.2
110.00	H	4500	4500	6052.4	6052.3	6051.6	6051.6
401.00			9850			6067.3	6066.9
111.00	I	10000		6067.4	6067.4	(6067.8)	(6067.4)
402.00			10774			6070.6	6067.0
403.00			11918			6075.6	6075.2
404.00			13097			6079.4	6078.4
405.00			14546			6084.4	6082.7
.20	J	15500	15500	6087.3	6087.3	6088.9	6087.4
.10		18000	18000		6098.9	6099.2	6098.2
1.00	K	19900	19900	6103.8	6103.8	6105.6	6106.0
2.00		21600	21600		6111.2	6110.3	6110.1

* The May 4, 1989 FIS study used a 1976 version of program HEC-2 updated in 1982. The same data was re-run using a 1988 version updated in April 1990. Cross-sections were surveyed in 1973. Elevations in ft NGVD 1929. Q: 23,300 cfs.

** Range 111 was not included in the "EXISTING" AND "IMPROVED" models since it was only 150 feet upstream of R1 and was not resurveyed in 1996. Values in parenthesis are interpolated.

TABLE 8

COMPARISON OF 100-YEAR FLOOD WATER-SURFACE ELEVATIONS FOR AREA 9

RANGE LABEL	1996 DISTANCE	FIS DIST. FEET	FIS REGULATORY	FIS RERUN	1996 EXISTING	1996 IMPROVED
9.05	3908.00	3890.00		6158.8	6159.0	6158.3
9.10	3958.00	3940.00	6158.8*	6158.9	6159.3	6158.4
9.20	3996.00	3978.00		6158.9	6159.3	6158.4
9.30	4046.00	4028.00		6159.1	6159.7	6158.4
10.00(N)	4358.00	4340.00		6160.0	6160.4	6158.6
902.00	4681.00				6163.2	6162.9
903.00	5271.00				6165.3	6165.3
903.20	5466.00				6165.7	6165.6
903.80	5801.00				6166.4	6166.0
11.00	6036.00	6270.00**		6169.5	6166.9	6166.6
904.00	6121.00				6167.2	6167.1
904.50	6974.00				6169.7	6169.2
905.00	8074.00				6173.9	6172.2
12.00	8224.00	7900.00**		6174.2	6174.9	6173.9
13.00	9974.00	9650.00		6179.9	6180.0	6181.1
14.00(O)	11674.00	11350.00	6187.9	6187.0	6186.8	6186.5

*The CWSEL elevation for section 10.00 is listed as 6159.45 in the computer output listing for the FIS study, while the CWSEL for section 9.10 was listed as 6158.82. It appears that the elevation for 9.10 was mistakenly listed as the elevation for section 10.00 in the 4 May 1989 FEMA Flood Insurance Study Report.
**The distances in the FEMA data did not appear to be consistant with the actual location of the Sediment Ranges 11 and 12 even when channel changes were considered. Discharge: 23,300 cfs

TABLE 9

COMPARISON OF 100-YEAR FLOOD WATER-SURFACE ELEVATIONS FOR AREA 10

RANGE LABEL	DISTANCE FEET	FIS REGULATORY	FIS RERUN	1996 EXISTING	1996 IMPROVED
17.00(P)	.00	6206.4	6206.4	6206.4	6206.4
18.00	1960.00		6213.4	6211.3	6211.3
19.00	3540.00		6219.6	6219.0	6219.0
20.00(Q)	5320.00	6224.8	6226.1	6224.8	6224.8
21.00	7037.00		6232.9	6231.5	6231.6
22.00	8590.00		6237.9	6236.9	6237.4
28.00	9790.00		6242.8	6240.9	6241.9
28.50	10710.00			6244.3	6243.5
29.00(R)	11690.00	6248.5	6248.4	6248.8	6248.3
30.00	12770.00		6256.0	6254.1	6253.3
31.00	14495.00		6261.3	6263.6	6262.0

Discharge: 23,300 cfs

TABLE 10

AREA 1 VELOCITIES
FOR EXISTING CONDITIONS IN 1996 (FILE C1.T95)
Average Cross-Section Velocity in fps

	FLOW IN CFS				
	500-YR	100-YR	50-YR	10-YR	1997
RANGE	45000	23300	21900	18100	32027
105.00	6.12	5.86	5.61	4.96	5.82
201.00	4.93	3.49	3.43	3.25	4.17
202.00	6.74	5.83	5.73	5.40	6.22
203.00	7.68	6.10	5.96	5.57	6.85
204.00	6.02	5.31	5.28	5.22	5.57
205.00	6.91	5.76	5.68	5.41	6.28
205.10	4.02	3.22	3.15	3.01	3.57
107.80	4.96	4.56	4.55	4.54	4.72
107.90	4.67	3.92	3.86	3.70	4.26
108.00	4.60	3.73	3.66	3.48	4.08
108.10	4.51	3.65	3.57	3.39	3.95
108.20	4.65	3.81	3.75	3.57	4.10
109.00	6.32	4.71	4.58	4.22	5.44
110.00	4.54	3.62	3.55	3.49	4.15

TABLE 11

AREA 1 VELOCITIES
FOR RESTORED CHANNEL (FILE I1B.T95)
Average Cross-Section Velocity in fps

	FLOW IN CFS				
RANGE	45000	23300	21900	18100	32027
105.00	6.12	5.86	5.61	4.96	5.82
201.00	4.97	3.53	3.47	3.30	4.21
202.00	8.76	7.37	7.19	6.65	7.98
203.00	8.49	6.66	6.52	6.05	7.54
204.00	5.45	4.75	4.73	4.66	5.02
205.00	8.62	7.14	7.02	6.85	7.85
205.10	4.21	3.83	3.82	3.89	4.09
107.80	4.33	4.04	4.00	3.82	4.25
107.90	3.74	3.04	2.98	2.76	3.40
108.00	4.61	4.07	4.03	3.92	4.30
108.10	4.44	3.68	3.62	3.54	4.03
108.20	5.20	4.67	4.65	4.71	4.89
109.00	5.93	4.31	4.18	3.82	5.03
110.00	4.78	3.91	3.92	3.92	4.35

Note: Ranges 105, 108, 109, 110 Surveyed in 1988. Above-water portion of Range 205.1 from 1996 topography, below-water estimated. Ranges 107.8, 107.9, 108.1, 108.2 based on survey of range 108.

TABLE 12

AREA 4 VELOCITIES
FOR EXISTING CONDITIONS IN 1996 (FILE C4.T95)
Average Cross-Section Velocity in fps

	FLOW IN CFS				
	500-YR	100-YR	50-YR	10-YR	1997
RANGE	45000	23300	21900	18100	32027
109.00	17.03	6.52	6.01	4.59	6.02
110.00	10.19	3.97	3.66	3.80	3.46
401.00	10.55	3.83	4.05	3.57	4.98
402.00	10.24	4.34	4.21	4.45	4.14
403.00	10.60	3.05	3.03	2.88	3.56
404.00	11.59	3.84	3.77	3.71	4.21
405.00	12.70	5.79	5.77	5.71	6.00
.20	13.65	5.81	5.74	5.47	6.18
.10	14.67	5.87	5.78	5.58	6.40
1.00	11.58	4.17	4.07	3.79	4.72
2.00	8.53	5.70	5.65	5.53	5.82

TABLE 13

AREA 4 VELOCITIES
FOR RESTORED-CHANNEL (FILE C4.T95)
Average Cross-Section Velocity in fps

	FLOW IN CFS				
	500-YR	100-YR	50-YR	10-YR	1997
RANGE	45000	23300	21900	18100	32027
109.00	17.03	6.52	6.01	4.59	6.02
110.00	10.19	3.97	3.66	3.80	3.46
401.00	11.11	4.19	4.41	3.91	5.44
402.00	10.15	6.00	5.79	5.71	5.93
402.00	10.15	6.00	5.79	5.71	5.93
403.00	9.41	3.23	3.25	3.10	3.53
404.00	11.58	4.33	4.30	4.09	4.72
405.00	12.77	8.80	8.80	8.65	8.24
.20	15.71	5.90	5.77	5.38	6.83
.10	13.85	8.20	8.23	8.25	7.99
1.00	11.37	3.81	3.71	3.41	4.44
2.00	8.42	6.04	6.04	5.88	6.02

Note: Ranges 109, 110, .20, .10, 1, and 2 were surveyed in 1988.

TABLE 14

AREA 9 VELOCITIES
FOR EXISTING CONDITIONS IN 1996
Average Cross-Section Velocity in fps

RANGE	FLOW IN CFS 32027	23300	21900	18100
9.05	8.29	7.43	7.28	6.84
9.10	7.81	6.96	6.81	6.38
9.20	8.01	7.18	7.03	6.61
903.00	7.18	6.32	6.16	5.74
10.00	9.96	8.77	8.56	8.05
902.00	5.55	4.91	4.79	4.48
903.00	4.60	4.10	4.01	3.75
903.20	4.79	4.38	4.31	4.10
903.80	6.12	6.08	6.06	6.01
11.00	6.29	6.23	6.22	6.15
904.00	5.91	5.70	5.66	5.57
904.50	5.39	5.12	5.08	5.05
905.00	6.00	5.37	5.24	4.88
12.00	5.84	5.21	5.10	4.75
13.00*	7.91	7.74	7.98	7.77
14.00*	4.75	4.15	4.07	3.75

TABLE 15

AREA 9 VELOCITIES
FOR RESTORED CHANNEL
Average Cross-Section Velocity in fps

RANGE	32027	23300	21900	18100
9.05	5.47	4.65	4.50	4.09
9.10	5.42	4.60	4.46	4.05
9.20	5.55	4.73	4.59	4.17
9.30	6.06	5.25	5.11	4.71
10.00	11.27	10.15	9.94	9.43
902.00	5.71	5.10	4.99	4.64
903.00	4.45	3.96	3.87	3.59
903.20	4.84	4.47	4.40	4.21
903.80	6.58	6.81	6.84	6.80
11.00	7.31	7.51	7.42	7.11
904.00	6.69	6.66	6.60	6.36
904.50	5.33	5.01	4.98	4.94
905.00	8.49	8.61	8.47	8.32
12.00	6.14	5.32	5.18	4.78
13.00	6.23	5.64	5.56	5.47
14.00	5.05	4.41	4.31	4.02

Note: Ranges 13 and 14 surveyed in 1988. Ranges 903.2, 903.8, 904.5, and 12 used aerial photogrammetry above-water, and interpolated or estimated values for portions of the profile below low-water (3800 cfs). Other Ranges were surveyed in 1996.

TABLE 16

AREA 10 VELOCITIES
FOR EXISTING CONDITIONS IN 1996 (FILE C10.T95)
Average Cross-Section Velocity in fps

	FLOW IN CFS				
	1997	100-YR	50-YR	10-YR	LOW
RANGE	32027	23300	21900	18100	3800
17.00	8.47	5.08	4.97	4.58	1.40
18.00	7.28	10.46	10.67	10.68	9.87
19.00	6.48	5.32	5.21	5.01	3.90
20.00	5.64	5.48	5.41	5.17	4.25
21.00	7.08	6.41	6.33	6.07	4.76
22.00	6.41	6.15	6.08	5.89	5.48
28.00	3.20	2.89	2.87	2.81	2.29
28.50	7.93	7.44	7.46	7.37	5.82
29.00	3.74	3.47	3.43	3.50	3.18
30.00	7.89	7.47	7.42	7.25	4.81
31.00	5.55	5.07	5.01	4.84	4.04

TABLE 17

AREA 10 VELOCITIES
FOR EXISTING CONDITIONS IN 1996 (FILE I10.T95)
Average Cross-Section Velocity in fps

	FLOW IN CFS				
RANGE	32027	23300	21900	18100	3800
17.00	8.47	5.08	4.97	4.58	1.40
18.00	7.28	10.46	10.67	10.68	9.87
19.00	6.48	5.32	5.21	5.01	3.90
20.00	5.54	5.40	5.33	5.09	4.45
21.00	6.89	6.31	6.22	6.00	4.79
22.00	9.57	8.71	8.56	8.02	6.21
28.00	2.76	2.60	2.70	2.68	2.27
28.50	7.55	8.60	9.10	8.27	4.60
29.00	4.09	3.95	3.84	3.91	3.72
30.00	9.05	8.83	8.74	8.46	4.55
31.00	6.12	5.54	5.47	5.35	3.71

Note: Ranges 17,18, 19, 30, 31 surveyed in 1988. Above-water portion of Range 28.5 from 1996 topography, below low-flow channel estimated. Others surveyed in 1996.

AREA 10

VOLUME CHANGE 1954 TO 1988 AND 1954 TO 1996

SECTION NUMBERS		1954 - 1988 REACH VOLUME CHANGE CU YDS DATA SET 1- 2	1954 - 1996 REACH VOLUME CHANGE CU YDS DATA SET 1- 3	
18.00 -	19.00	-120240.2	-120240.2	
19.00 -	20.00	-129283.5	-141542.4	
20.00 -	21.00	-158560.3	-201470.1	
21.00 -	22.00	-110559.2	-198098.1	
22.00 -	28.00	-13657.1	-34144.3	
28.00 -	29.00	7212.4	-178984.3	
29.00 -	30.00	48023.6	-15026.3	
30.00 -	31.00	34950.6	34950.6	
TOTAL VOLUME CHANGE:		-442113.7	-854555.2	CY